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LOUISIANA COASTAL PROTECTION AND RESTORATION TECHNICAL REPORT

February 2008

U. S. Army Corps of Engineers
New Orleans District
Mississippi Valley Division

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List of Acronyms

ADCIRC	ADvanced CIRCulation (wind and wave modeling system)
CLEAR	Coastal Louisiana Ecosystem Assessment and Restoration (model)
CPRA	Coastal Protection and Restoration Authority (State of Louisiana)
CWPPRA	Coastal Wetlands Planning, Protection, and Restoration Act
EQ	Environmental Quality
GIS	Geographic Information System
GIWW	Gulf Intracoastal Waterway
GOHSEP	Governor's Office of Homeland Security and Emergency Preparedness
IPAWS	Integrated Public Alert and Warning System
IPET	Interagency Performance Evaluation Task force
JPM-OS	Joint Probability Method-Optimum Sampling
LACPR	Louisiana Coastal Protection and Restoration
LCA	Louisiana Coastal Area (*Ecosystem Restoration Study*, 2004)
MCDA	Multi-Criteria Decision Analysis
MRGO	Mississippi River-Gulf Outlet
MsCIP	Mississippi Coastal Improvements Program
NAVD88	North American Vertical Datum, 1988
NED	National Economic Development
NEPA	National Environmental Policy Act
NER	National Ecosystem Restoration
OSE	Other Social Effects
PU	Planning Unit
RED	Regional Economic Development
RIDF	Risk-Informed Decision Framework
USACE	U.S. Army Corps of Engineers
WRDA	Water Resources Development Act

Glossary

100-year Design
A hurricane risk reduction design (e.g. a levee design) based on a flood elevation that statistically has a 1% chance of being equaled or exceeded in any given year. Similarly, a 50-year design is based on a flood elevation that has a 2% chance of being equaled or exceed in any given year (divide 1 by the return period and multiply by 100 to get the percent chance).

ADCIRC
The ADvanced CIRCulation hydrodynamic model simulates water levels and is used to calculate the design still water level in storm events.

Alternative
For LACPR, an alternative incorporates one or more structural, nonstructural, and/or coastal restoration measures for risk reduction. Alternatives emerge from the plan formulation process.

Barrier Islands
A linear landform created by the interaction between water and sediments within or extending into a body of water. The barrier islands along the Louisiana coast are a result of sediments deposited by the Mississippi River during its wandering over the past several thousand years. Examples of this phenomenon are the Isles Dernieres chain west of Terrebonne Bay and the Breton Island chain east of St. Bernard Parish.

Baseline Conditions
The baseline conditions are the no-action conditions assuming none of the LACPR alternatives are implemented. The baseline conditions include outputs of the hydromodeling analysis, which statistically predict the hurricane threat; an inventory of economic and environmental assets; and descriptions of existing projects designed to reduce risk to those assets.

Category 5 Hurricane
A storm on the Saffir-Simpson Hurricane Scale having winds greater than 155 mph (135 kt or 249 km/hr). Storm surges are generally greater than 18 feet above normal. Only three verified Category 5 Hurricanes have made landfall in the United States since recordkeeping began: The Labor Day Hurricane of 1935 (Florida Keys), Hurricane Camille in 1969 (Mississippi and Louisiana), and Hurricane Andrew in August 1992 (Florida and Louisiana). For LACPR, the Category 5 hurricane event is represented by a range of frequencies, i.e. the 400-year event represents a “low” Category 5 hurricane and the 1000-year event represents a “high” Category 5 event.

Chenier
A geologic formation found within the Prairie Marshes of coastal Vermilion and Cameron Parishes of southwest Louisiana that consists of ancient beach lines that, in most cases, parallel the Gulf of Mexico. These intermittent shell ridges are called "cheniers" because of the live oaks that grow on them; the term cheniere is a French term for oak. The ridges developed from sediment that escaped the delta over the past 3,000 years and was transported and deposited along the coast of western Louisiana and periodically eroded as the river shifted courses.

CLEAR Model
The CLEAR model (which stands for “Coastal Louisiana Ecosystem Assessment and Restoration”) is a modeling system developed by the Department of Natural Resources’ Coastal Restoration Division in

collaboration with the Center for Ecology and Environmental Technology at Louisiana State University to link scientific understanding of the following four major features of the Mississippi River Delta: (1) physical process (river and coastal ocean); (2) geomorphic features; (3) ecological succession (or state change); (4) water quality conditions. For LACPR, the CLEAR model was used to predict coastal wetland land loss by the year 2060.

Comprehensive
In general, comprehensive means "large in scope or content." The term comprehensive has been used for LACPR in the following three ways:

> **(1) Comprehensive Alternatives** are plans that contain all three types of **risk reduction measures**—nonstructural, structural, and coastal restoration—presenting a **multiple lines of defense strategy** and providing comparable levels of risk reduction to all economic assets in the surge impacted areas.
>
> **(2) Comprehensive Category 5 Protection -** As required by the Congressional authority, a preliminary technical report was submitted to Congress for comprehensive Category 5 protection.
>
> **(3) Comprehensive Hurricane Protection Analysis and Design -** As required by the Congressional authority, the LACPR effort includes a comprehensive analysis and design that presents a full range of flood damage reduction, coastal restoration, and hurricane risk reduction measures for South Louisiana.

Depth-Damage Relationships
Depth-damage relationships are used to indicate the percentage of the structural and content value that was damaged at each depth of flooding for residential and non-residential properties. Damage percentages were determined for each one-half foot increment from one foot below first-floor elevation to two feet above first floor, and for each 1-foot increment from 2 feet to 15 feet above first-floor elevation.

Frequency-Damage Relationships
The potential flood damage associated with each of the five frequency storm events (10-, 100-, 400, 1000, and 2000-year events) for each of project alternatives. The frequency-damage relationships were calculated for three levels of confidence (10 percent, 50 percent, and 90 percent) to account for hydrologic uncertainty.

Joint Probability Method
A statistical tool involving an assumption of independence of storm parameters so that the combined probability of a particular hurricane is the product of the probabilities of each of the governing parameters. These parameters include forward speed, storm radius, central pressure depression, and storm position; a dependence on track angle is assumed and accounted for by separation of the storm into directional families.

Measure
A component of alternative plans for risk reduction. Categories of risk reduction measures include structural, non-structural and coastal restoration. See also **Risk Reduction Measure.**

Metric
A parameter for measuring the performance of objectives.

Monte Carlo Simulation
A widely used class of computational algorithms for simulating the behavior of various physical and mathematical systems, and for other computations. They are distinguished from other simulation methods

(such as molecular dynamics) by being stochastic, that is nondeterministic in some manner – usually by using random numbers (in practice, pseudo-random numbers) – as opposed to deterministic algorithms. Because of the repetition of algorithms and the large number of calculations involved, Monte Carlo is a method suited to calculation using a computer, using many computer simulation techniques.

Mississippi River and Tributaries Project Design Flood
The Mississippi River and Tributaries Project Design Flood is a worst-case scenario derived for each location within the Mississippi River Basin, calculating water volumes for the purposes of designing risk-reduction measures.

Multi-Criteria Decision Analysis
Multi-criteria decision analysis is a discipline aimed at supporting decision-makers who are faced with making numerous and conflicting evaluations, highlighting these conflicts and deriving a way to come to a compromise in a transparent process.

Multiple Lines of Defense
The Multiple Lines of Defense concept (Lopez 2006) integrates the following natural and engineered risk reduction elements in coastal Louisiana: (1) the Gulf of Mexico shelf, (2) barrier islands, (3) bays or sounds, (4) marsh landbridges, (5) ridges, (6) highways, (7) flood gates, (8) levees, (9) pump stations, (10) elevated buildings, and (11) evacuation routes.

No-Action Alternative
The USACE is required to consider the option of "no action" as one of the alternatives in order to comply with the requirements of the National Environmental Policy Act (NEPA). With the no-action plan, which is synonymous with the without-project condition, it is assumed that no project would be implemented by the Federal Government or by local interests to achieve the planning objectives. The no-action plan forms the basis, which all other alternative plans are measured against.

Plan or Alternative Plan
In general, a plan is any detailed scheme, program, or method worked out beforehand to accomplish an objective. For LACPR, an alternative plan incorporates one or more structural, nonstructural, and/or coastal restoration measures for risk reduction. Alternative plans emerge from the plan formulation process.

Relative Sea Level Rise
Relative sea level rise is often segmented into a global increase in water mass (global **sea level rise**), a rise in local water level due to density changes in the water, and a drop in local land elevation (**subsidence**).

Residual Risk
The risk that remains after a flood damage reduction project has been implemented (NRC 2000).

Return Period or Interval
Average period of time between occurrences of a given hurricane or tropical storm event or occurrences of a given storm surge, e.g. the 100-year storm surge event.

Ridges
Geographical features along the Louisiana coast where wind and wave action has built linear barriers of sand and soil parallel to the coastline. These features are found most often in the **Chenier** Plains of Southwest Louisiana.

Risk
The probability for an adverse outcome. Risk = (Frequency of an event) x (Probability of occurrence) x (Consequences).

Risk Informed Decision Framework
A new decision framework that augments the six-step USACE planning process by incorporating specific techniques and methods from risk analysis and multi-criteria decision analysis. The approaches incorporated within the risk informed decision framework enhance communication and collaboration among decision-makers and stakeholders by providing structure and mechanisms for capturing information about attitudes and values of decision-makers and stakeholders that are essential to defining objectives, metrics, and weights for metrics that reflect priorities.

Risk Reduction Measure
A component of alternatives for risk reduction. Categories of risk reduction measures include structural, non-structural and coastal restoration. See also **Measure.**

Saffir-Simpson Hurricane Scale
The Saffir-Simpson Hurricane Scale is a 1-5 rating based on a hurricane's intensity at a given point in time. This scale is used to give an estimate of the potential property damage and flooding expected along the coast from a hurricane landfall. Wind speed is the determining factor in the scale, as storm surge values are highly dependent on the slope of the continental shelf and the shape of the coastline in the landfall region.

Sea Level Rise
Sea level rise is an increase in sea level. Multiple complex factors may influence this change.

Stage-Damage Relationships
A water elevation NAVD88 (2004.65 epoch) was calculated for each census block. Flood damages were calculated at one-foot increments from the beginning damage elevation to an elevation where damages for all the structural categories have reached a maximum amount of damage.

Stage-Frequency Data
Stage-frequency data were derived from the hydromodeling results for each planning subunit under existing and future without-project and with-project conditions. Stages were provided for five frequency storms (10-, 100-, 400-, 1000-, and 2000-year events). The stage-frequency data were combined with the **stage-damage relationships** to develop **frequency-damage relationships** for each planning subunit. The frequency-damage relationships are then used to derive the expected annual damages.

Subsidence
Subsidence is the motion of a surface (usually, the Earth's surface) as it shifts downward relative to a datum such as sea level.

Standard Project Hurricane
A hypothetical hurricane intended to represent the most severe combination of hurricane parameters that is reasonably characteristic of a specified region, excluding extremely rare combinations. It is further assumed that the standard project hurricane would approach a given project site from such direction, and at such rate of movement, to produce the highest hurricane surge hydrograph, considering pertinent hydraulic characteristics of the area. Based on this concept and on extensive meteorological studies and probability analyses, a tabulation of “Standard Project Hurricane Index Characteristics” was mutually agreed upon by representatives of the U.S. Weather Service and the USACE (NOAA 1979).

Still Water Level
The elevation of the water surface without waves.

Uncertainty
Lack of confidence in a risk prediction.

Velocity Zones or V-zones
Areas closest to the shoreline subject to wave action, high-velocity flow, and erosion from a 100-year event.

Water Level
The height of the water surface measured above a datum.

With-Project Conditions
The with-project conditions are the projected changes in future conditions as the result of implementing one or more LACPR alternatives.

Without-Project Conditions
The without-project conditions are the projected changes in future conditions resulting from no action, or not implementing any of the LACPR alternatives.

Section 1. Introduction and Background

Hurricanes and tropical storms are part of Louisiana's history and culture. The catastrophic losses resulting from the hurricanes of 2005, and the greatest tidal surge to hit the mainland of the United States in recorded history, however, highlighted the need to take a more systematic approach to hurricane risk reduction. In response to the destruction caused by Hurricanes Katrina and Rita, both the Louisiana Legislature and the United States Congress provided legislative directives to their respective agencies to investigate and integrate hurricane risk reduction and coastal restoration for South Louisiana. Development of plans to meet these directives was undertaken as a joint effort of the Federal government and the State of Louisiana. Although the State and Federal legislative directives are not identical, they share the common fundamental objective to create the first plan in Louisiana's history designed to fully integrate hurricane risk reduction for coastal communities and industries with the restoration of the State's rapidly deteriorating coastal wetlands.

Residents in vulnerable areas throughout southern Louisiana make up a work force that produces vital goods and services for the Nation that are unavailable in other regions. The location of the New Orleans metropolitan area takes advantage of critical national transportation corridors; the Mississippi River is the main water-based transportation route serving the central United States. Until the 18th century, the mouth of the Mississippi River was frequently impassible due to log jams and shoals. The site of the City of New Orleans was chosen because it provided shipping access to the Mississippi River via Breton Sound, Lake Borgne, Lake Pontchartrain and various bayous without having to navigate the treacherous river mouth. As the United States grew, New Orleans grew with its port attracting industry and associated maritime development.

Following World War I, construction of the Gulf Intracoastal Waterway (GIWW) encouraged further industrial development along the Louisiana coast for defense manufacturing and energy production. Ports located in South Louisiana grew to become the largest collective port facility in the United States. The State is also home to three of the top ten commercial fisheries ports as well as the Nation's only offshore oil port and support industry which contribute to vital domestic energy security. In January 2006, coastal Louisiana was reported to be home to over 2.4 million residents (55% of the State's population) as well as related business and industry. These residents play a vital role in key sectors of the Nation's economy.

The complex and changing nature of coastal Louisiana's environment and communities creates a challenge for planners in the short term; these and other challenges are expected to continue well into this century. Assembling a diverse team to work with local interests and the public offers the best approach for formulating a plan that simultaneously meets technical requirements and achieves a level of public understanding and acceptance. The LACPR effort is the result of collaboration by the U.S. Army Corps of Engineers (USACE), Louisiana's Coastal Protection and Restoration Authority (CPRA) and other State agencies, Federal agencies, non-USACE scientists and academics, non-governmental organizations, the Dutch Rijkswaterstaat, Dutch Water Partnership, independent technical reviewers, external peer reviewers, private engineering firms (U.S. and Netherlands), landowners, stakeholders, and the public.

Purpose and Contents of the Technical Report

The purpose of this Technical Report is to describe the Louisiana Coastal Protection and Restoration (LACPR) effort that is being undertaken in response to the Energy and Water Development Appropriation Act of 2006 passed in November 2005 and the Department of Defense, Emergency Supplemental Appropriations to Address Hurricanes in the Gulf of Mexico, and Pandemic and Influenza Act, 2006 passed on December 30, 2005, as part of the Defense Appropriations Act, P.L 109-148. Under these acts, Congress and the President directed the Secretary of the Army, acting through the Chief of Engineers to conduct a comprehensive hurricane protection analysis and design; to develop a full range of flood control, coastal restoration, and hurricane protection measures exclusive of normal policy considerations for South Louisiana; and to submit a final technical report for "Category 5" protection within 24 months.

The USACE has made significant progress on the LACPR effort but was not in the position to submit the final technical report in December 2007. Additional time is needed to complete a comprehensive hurricane analysis and design for South Louisiana due to the engineering, environmental, and economic complexities.

This Technical Report expands on information presented in the LACPR Preliminary Technical Report that was submitted to Congress in July 2006 as well as the April 2007 LACPR Plan Formulation Atlas. The LACPR Preliminary Technical Report and Plan Formulation Atlas are available online at *www.lacpr.usace.army.mil*.

This report describes the methodologies used to perform the technical evaluation and the process for using this information to engage decision makers, stakeholders, and the public in future decisions for reducing risk to South Louisiana. This report also discusses the path forward with stakeholders and decision makers to complete the planning process and to make recommendations.

The LACPR effort has, and will continue to be integrated with the Mississippi Coastal Improvements Program (MsCIP) efforts to ensure a consistent systems approach to modeling storm events, data sharing, alternatives analysis, and lessons learned, as appropriate.

The LACPR effort is also closely tied with the State of Louisiana's master plan for coastal restoration and hurricane protection entitled *Integrated Ecosystem Restoration and Hurricane Protection: Louisiana's Comprehensive Master Plan for a Sustainable Coast*, which the Louisiana Legislature approved on May 30, 2007.

The information presented in this report is not suitable for making project authorizations, appropriations, or non-governmental decisions. This report is based on thousands of pages of pre-decisional supporting documentation that will undergo external peer review by the National Academy of Sciences and independent technical review and is therefore subject to change.

Authority

In response to the destruction caused by Hurricanes Katrina and Rita, both the Louisiana Legislature and the United States Congress provided legislative directives to their respective agencies to investigate and create the first plan in Louisiana's history designed to fully integrate hurricane risk reduction for coastal communities and industries with the restoration of the State's rapidly deteriorating coastal wetlands. The Energy and Water Development Appropriation Act, 2006 (Public Law 109-103) reads as:

> *''Provided further, That using $8,000,000 of the funds provided herein, the Secretary of the Army, acting through the Chief of Engineers, is directed to conduct a comprehensive hurricane protection analysis and design at full federal expense to develop and present a full range of flood control, coastal restoration, and hurricane protection measures exclusive of normal policy considerations for South Louisiana and the Secretary shall submit a preliminary technical report for comprehensive Category 5 protection within 6 months of enactment of this Act and a final technical report for Category 5 protection within 24 months of enactment of this Act: Provided further, That the Secretary shall consider providing protection for a storm surge equivalent to a Category 5 hurricane within the project area and may submit reports on component areas of the larger protection program for authorization as soon as practicable: Provided further, That the analysis shall be conducted in close coordination with the State of Louisiana and its appropriate agencies.''*

Additional legislation was provided through the Department of Defense Appropriation Act, 2006 (Public Law 109-148), signed on December 30, 2005, that is amended as follows:

> *"…that none of the $12,000,000 provided herein for the Louisiana Hurricane Protection Study shall be available for expenditure until the State of Louisiana establishes a single state or quasistate entity to act as local sponsor for construction, operation and maintenance of all of the hurricane, storm damage reduction and flood control projects in the greater New Orleans and southeast Louisiana area…"*

The establishment of the Coastal Protection and Restoration Authority (CPRA) in December 2005 by the State of Louisiana complied with Public Law 109-148 as described above.

Policy Considerations

LACPR presents a very complex water resource management challenge due to the range of interrelated human and environmental factors to be addressed, the size of the planning area, the requirement for new hydromodeling methodologies, and the coordination of stakeholder involvement. For these reasons, as well as the magnitude of the hurricane damage in 2005, Congress directed the LACPR analysis to be conducted "exclusive of normal policy considerations."

Congress also directed a technical report rather than a reconnaissance or feasibility report as described by normal USACE policy. The technical report will contain many of the same components as a reconnaissance or feasibility report, such as presenting the results of the formulation and evaluation of alternatives. As outlined by the Congressional direction, the technical report will contain a "comprehensive hurricane protection analysis and design…to develop and present a full range of flood control, coastal restoration, and hurricane protection measures…for comprehensive Category 5 protection."

Accomplishments of LACPR

Since December 2005, the LACPR team has faced a unique challenge in conducting a comprehensive hurricane risk reduction analysis and design for the approximately 16,000 square miles of South Louisiana. The magnitude of data, and the tools required to analyze the data, far exceed any prior USACE hurricane risk reduction efforts. To this end, the LACPR team has developed the following processes to facilitate the technical evaluation:

- **Risk-based Hurricane Frequency Simulation –** One of the most significant accomplishments was the development and application of numerical models to replicate hurricane surges and to statistically determine the potential frequency of events at individual locations across the entire coast. The models address all of coastal Louisiana for storm frequency events of the rarest magnitude including a range of "Category 5" hurricanes. The Federal government adopted these models for the rebuilding of the New Orleans levee system, for determining flood insurance maps, and for evaluation of the Mississippi Gulf Coast.

- **Economic Evaluation -** As a means to process data for approximately 60,000 census data blocks under multiple future scenarios, the LACPR team developed a customized geographic information system (GIS), which utilized remotely-sensed data to assess the damages to residential and nonresidential structures, their contents, and vehicles as well as agricultural resources, roads and railroads in the LACPR planning area. The application was also used to determine the number of structures, population, employment, income, and output affected by the stages associated with various frequency flood events. This inventory allows the LACPR team to evaluate alternatives and interact with stakeholders using a flexible and meaningful level of outputs.

- **Cultural Resources Evaluation –** For the same reasons as mentioned above, cultural resources were placed into a GIS database for South Louisiana to serve LACPR and future USACE efforts.

- **Coastal Restoration Evaluation –** Louisiana's rapidly eroding wetlands have been a concern for a number of years. In addition to the ecological evaluation of the coastal wetlands, the LACPR effort sought to quantify the risk reduction benefits provided by wetlands. An independent Habitat Evaluation Team was established by LACPR, which developed a practical application to evaluate the multitude of land building performance options based on Mississippi River diversions.

- **Plan Formulation –** In order to catalogue and begin screening the extensive numbers of risk reduction measures proposed by various groups and individuals, the LACPR team prepared and made public the LACPR Plan Formulation Atlas dated April 16, 2007. The Atlas identifies hundreds of measures which could result in millions of potential risk reduction alternatives. Those alternatives were then screened down to a set of better defined alternatives for evaluation and comparison.

- **Multi-Criteria Decision Analysis –** In order to present alternatives that equitably address the many vital concerns to stakeholders, multiple criteria need to be evaluated and compared. While a number of tools exist to compare the over 100 alternative plans brought forth in this document, there are also many competing interests and varying perceptions of risk. In response to limitations in traditional USACE methods, the LACPR team has begun to use multi-criteria decision analysis (MCDA) as a tool for objectively comparing alternatives based on stakeholder values.

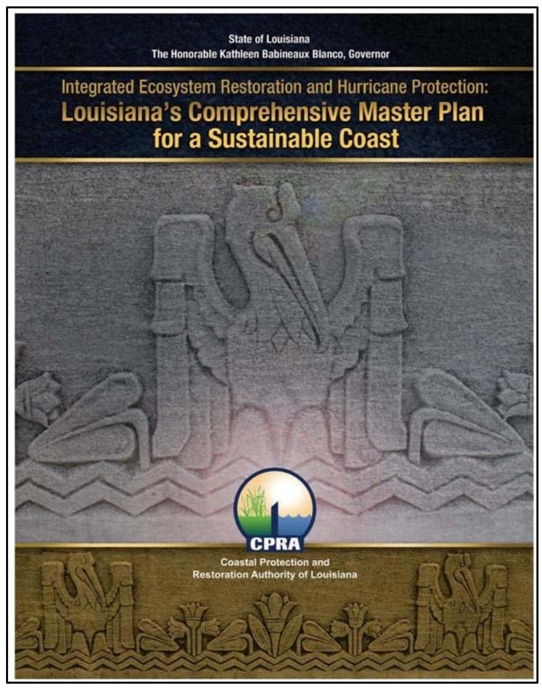
- **Public and Stakeholder Involvement –** The LACPR team has solicited participant feedback at numerous meetings across coastal Louisiana. Beginning in September 2006, a decision analysis team was established to develop a transparent, stakeholder involved evaluation process. This public and stakeholder involvement effort will be used to help arrive at plan selection. This type of involvement and integration will continue and expand as the LACPR effort moves forward and further incorporates the risk-informed multi-criteria decision analysis tool.

Coordination with the State of Louisiana

In 2005, the Louisiana Legislature restructured the State's Coastal Wetlands Conservation and Restoration Authority to form the Coastal Protection and Restoration Authority (CPRA) calling for:

- A long-term comprehensive coastal protection plan combining hurricane protection and the protection, conservation, restoration, and enhancement of coastal wetlands and barrier shorelines or reefs.

- A plan that addresses hurricane protection and coastal restoration efforts from both short-term and long-range perspectives and incorporates structural, management, and institutional components of both efforts.



Cover of Louisiana's State Master Plan

The CPRA is the single State entity with the authority to focus development and implementation efforts for comprehensive coastal protection and restoration and to interface with the USACE on LACPR coordination. The CPRA was directed to develop the State Master Plan in order to coordinate the efforts of other ongoing risk reduction efforts, particularly those of the USACE. Since LACPR is building from the State Master Plan, a common process was being applied for LACPR plan formulation and CPRA efforts to develop seamless hurricane risk reduction plans.

The State Master Plan has been completed and was approved unanimously by the Louisiana Legislature with final approval being provided on May 30, 2007. The State continues to work directly with the USACE on the LACPR effort. Continuing cooperation and partnership with the State of Louisiana is, and should be, an integral part of the LACPR effort.

The State Master Plan, which is available at *www.lacpra.org*, presents the State's conceptual vision of a sustainable coast. The relationship between the State and the USACE facilitates sharing of the best available scientific and engineering information and working closely with each program's partners and the public.

Federal Agency Involvement

Federal agencies have participated in the LACPR effort at the field, regional, and Federal level. Federal agencies assisted with plan formulation, technical assessment, development of evaluation metrics, and will participate in recommendations for action. The participation of the Federal agencies in these capacities does not in any way limit the prerogatives of the other participating agencies in exercising their statutory authorities and responsibilities. However, this collaborative approach creates strong working relationships and provides early recognition of multiple government priorities. Participating Federal entities include:

- Department of Homeland Security - Office of Gulf Coast Recovery, Federal Emergency Management Agency
- Environmental Protection Agency
- Department of the Interior – U.S. Fish and Wildlife Service, U.S. Geologic Survey, National Park Service, Minerals Management Services
- Department of Commerce – National Oceanic and Atmospheric Administration - National Marine Fisheries Service, National Weather Service
- Department of Agriculture - Natural Resources Conservation Service
- Department of Energy
- Department of Transportation - Maritime Administration, Federal Highway Administration
- U.S. Coast Guard

Parallel Efforts in Louisiana and Mississippi

Similar to the LACPR effort, Congress directed the USACE to conduct a comprehensive hurricane protection analysis for coastal Mississippi and to recommend improvements that would reduce hurricane and storm damage, reverse impacts of saltwater intrusion, preserve fish and wildlife and their habitats, prevent shoreline erosion, and other water resource purposes. The Mississippi Coastal Improvements Program (MsCIP) addresses that direction in coordination with the State of Mississippi's Coastal Restoration Initiative and with the LACPR effort. An Interim Report was submitted to Congress on June 30, 2006 recommending a series of near-term improvements as part of the MsCIP effort.

The LACPR and MsCIP efforts were coordinated during all phases, including planning, technical analyses, and stakeholder engagement. Coordination includes regular communication including face-to-face meetings. The teams are also using common planning, technical members and tools to further coordinate development of the plans. One element of the LACPR formulation process includes closely evaluating alternatives that could potentially increase water levels in Mississippi. A coordinated systems analysis of the tentatively selected plans for both areas is planned so that a system recommendation can be made. More details on the systems analysis can be found at the end of this document in the *LACPR Path Ahead* section.

The Hurricanes of 2005: Katrina and Rita

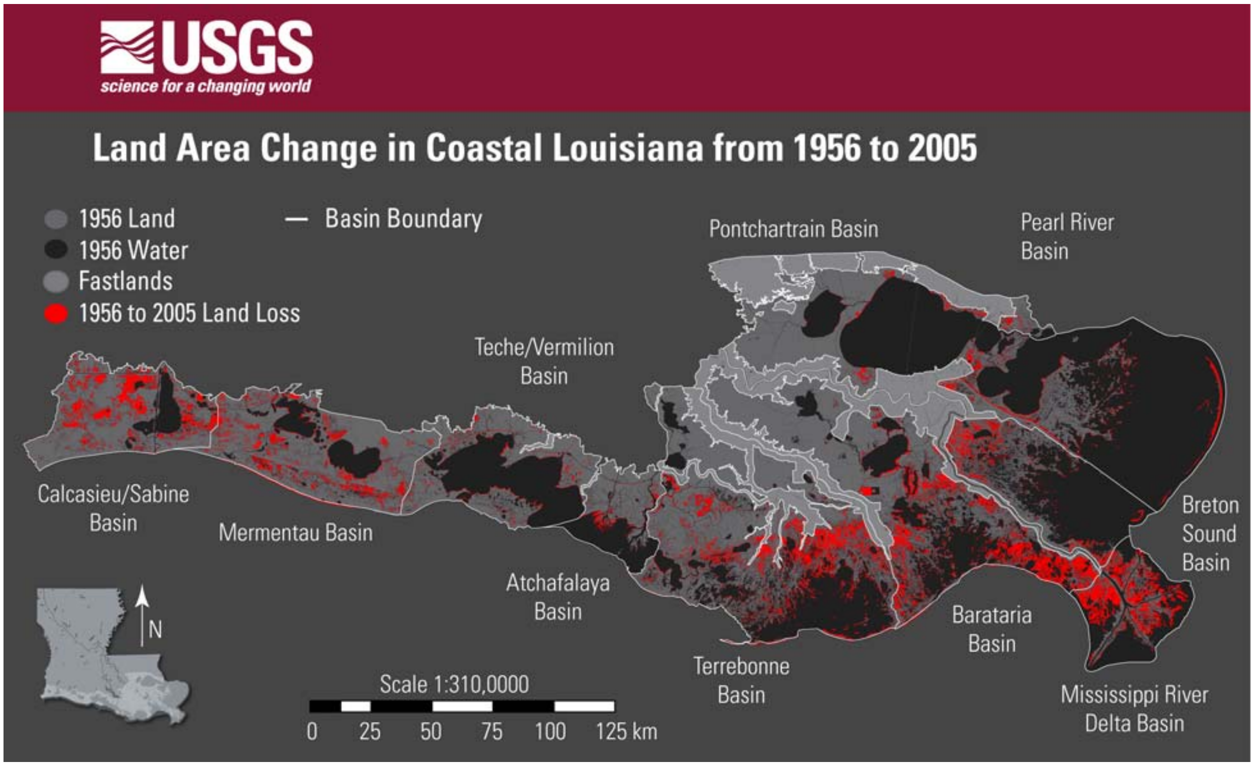
According to the Office of the Federal Coordinator for Gulf Coast Rebuilding, hurricanes Katrina and Rita affected 90,000 square miles—an area the size of Great Britain. During Hurricane Katrina, over 80 percent of New Orleans alone flooded—an area seven times the size of Manhattan. More than 1.5 million people were directly affected and more than 800,000 citizens were forced to live outside of their homes—the largest displacement of people since the great Dust Bowl migrations of the 1930s. However, unlike the Dust Bowl migrations which took place over a five to six year period, the displacement of people from the storms of 2005 was immediate. Also, unlike the Dust Bowl migrations where people knew that they would not be returning for some time, if ever, most of those fleeing the storms of 2005 fully expected to be returning to their homes no longer than two or three days later.

Hurricanes Katrina and Rita were two of the most costly national disasters to occur in the United States. In their Congressional Budget Office testimony of October 2005, Risk Management Solutions estimated the total losses of physical capital, including housing, consumer durable goods, and losses in the energy, private and public sectors, to be approximately $130 billion for both hurricanes.

Coastal Wetland Loss from the Hurricanes of 2005

The Louisiana coast is unique among the Gulf Coast states in that its coastal population centers are all buffered from the Gulf of Mexico by an expansive, although rapidly eroding coastal wetland system (see **Figure 1-1** below). Hurricanes Katrina and Rita also resulted in the destruction of more than 217 square miles of coastal wetlands during their landfalls. The loss attributed to these storms exceeds the wetland losses that had been projected to occur in the entire State over the next 20 years. Viewed in relation to New Orleans alone, all of the wetlands that were expected to erode in the New Orleans area over the next 50 years were lost in a single day during the landfall of Hurricane Katrina. In addition, Hurricane Katrina destroyed or substantially damaged about one half of the State’s barrier islands along the Gulf of Mexico.

Figure 1-1. Land area change in coastal Louisiana 1956 to 2005 including effects from the 2005 hurricanes.



The accelerated loss of Louisiana's coastal lands has been ongoing since at least the early 1900s with commensurate harmful effects on the ecosystem and future negative impacts to the economy of the region and the Nation. The USACE, the State of Louisiana, and others, under the authorization of the U.S. Congress, have been working for several years to combat coastal land loss, not only because of the role of coastal lands in storm protection, but also because of their vital contribution to the health of the natural environment, the regional and national economy, as well as the culture of South Louisiana. The alarming rate of land loss in coastal Louisiana has been raised as a national concern because it represents approximately 90 percent of the total coastal marsh loss occurring in the Nation (USACE, 2004). Of the hundreds of miles of shoreline, over 95 percent are suffering some form or level of erosion (LCA, 2007).

Coastal Land Loss Factors

Many studies have been conducted to identify the major contributing factors (e.g., Boesch et al., 1994; Turner, 1997; Penland et al., 2000), most studies agree that land loss and the degradation of the coastal ecosystem are the result of both natural and human induced factors, producing conditions where wetland vegetation can no longer survive or is directly extracted and wetlands are lost. Establishing the relative contribution of natural and human-induced factors is difficult. In many cases, the changes in hydrologic and ecologic processes manifest gradually over decades and in large areas, while other effects occur over single days and impact relatively localized areas.

Natural factors of coastal land loss and ecosystem degradation include geologic faulting, compaction of sediment, river floods, global sea level change, wave erosion, and tropical storm events. These factors have shaped the coastal Louisiana landscape for thousands of years (Kulp, 2000; Reed, 1995). Over millennia, sea level change and subsidence were offset by delta building in the Deltaic Plain and mudstream accretion in the Chenier Plain.

Human activities have impacted land loss both directly and indirectly. Wetlands have been lost in the construction of navigation channels, canals and flood control structures. The placement of the dredged material has contributed to wetland loss. Levees, that confine flood flows to their rivers, have contributed indirectly to wetland loss. Subsurface fluid withdrawal (oil, gas, water) may also be a major contributor to relative subsidence and resulting wetland loss (Morton et al, 2002). Some of these impacts are discussed below:

- Flood Control. Levees built for flood control have limited the delivery of sustaining freshwater, sediment, and nutrients of the Mississippi River and its distributaries to coastal wetlands. Accumulation of sediments, or vertical accretion, in wetland depends primarily on material brought in by river water, floodwaters, or winds. Living and dead organic matter produced locally by plants can add to the accretion. An accretion deficit can result from human intervention. Containment of flood flows is one intervention. Even where Mississippi River and distributary diversions are provided, reduced sediment availability from the Mississippi River has also resulted from upstream reservoirs, changes in agricultural practices and land uses, and bank stabilization measures.

- Navigation Channels and Canals. The construction of navigation channels connecting ports through the wetlands to the Gulf of Mexico, the Gulf Intracoastal Waterway stretching across the State and a vast network of canals built primarily to service the oil industry have led to direct land loss. Their construction also indirectly affects wetlands. The water courses have allowed saltwater intrusion and subjected inland areas to more dramatic tidal forces and wave action, thereby increasing erosion. Together with the elevated spoil bank construction, they have disrupted distribution of freshwater, sediment, and nutrients to wetland habitats by altering the natural hydrologic processes and tidal exchanges across the wetlands. This has lead to further wetland loss and impairment.

- Saltwater Intrusion. Saltwater intrusion can lead to extreme salinity changes. These salinity disruptions can cause changes in marsh type (e.g. from fresh to brackish marsh) and species composition. In some cases, saltwater intrusion has caused vegetation to die. Without protective vegetation, subsequent erosion converts former wetlands into open water (Flynn et al., 1995).

- Oil Well Production. Recent research has suggested a strong correlation between wetland loss and oil well extraction rates. Wetlands over or near oil wells have experienced loss associated with subsidence related to the extraction of fluids, especially in areas that have fault lines (Morton et al., 2006).

Without positive human intervention, land loss caused by erosion, subsidence, and other factors will continue.

Section 2. Setting the Stage for Improved Planning and Decision Making

The lessons learned from the hurricanes of 2005 and the intense hydromodeling effort that the USACE has undertaken since that time has advanced the understanding of hurricane risk to South Louisiana. That knowledge sets the stage for improving the USACE's planning, analysis, design, and decision making.

Lessons Learned Since the Hurricanes of 2005

Extensive internal and external review of USACE methodologies, assumptions, design standards, and decision-making processes related to the existing hurricane protection system in New Orleans and vicinity has occurred since 2005. The primary source of forensic data and evaluation of the performance of the system is the Interagency Performance Evaluation Task Force's (IPET) report (March 2007). The IPET report concludes:

1. **The System** - Planning and design methods must be system-based, allowing a more in-depth analysis of how a combination of structures and measures will perform together.

2. **The Storm -** Sophisticated models incorporating high-resolution spatial data and high-quality wind fields are essential to accurately characterize storm surge and waves, particularly in an area such as New Orleans.

3. **The Performance -** All hurricane risk reduction structures should be designed as part of a complete system-based approach to risk reduction, providing balanced and uniform levels of protection from the perspectives of time, level of hazard, and reliability, while still being conservative enough to accommodate unknowns.

4. **The Consequences -** Using a new information base from knowledge gained since Katrina, a comprehensive risk analysis can be developed for use in planning redevelopment of the devastated areas. In the case of environmental damage and losses, not nearly enough information is available on the long-term impact of saltwater intrusion or the conditions and rates of recovery that can be expected. Studies in this regard are on-going.

5. **The Risk -** At the current level of technology, no system can provide a guarantee of safety to the public. A key component to reducing risk to life and human safety is emergency-response preparedness and an efficient evaluation of danger prior to a storm.

The LACPR effort seeks to incorporate these lessons learned from IPET into the technical evaluation and planning process in order to develop better solutions for hurricane risk reduction throughout South Louisiana.

Dispelling Hurricane Myths

In 1969, Herbert Saffir and Bob Simpson developed a post-storm impact assessment tool to gauge the strength of hurricanes, the Saffir-Simpson Hurricane Scale. Many misconceptions about the strength of hurricanes have infused the public conscious, some of which are perpetuated by the common use of the Saffir-Simpson Hurricane Scale to determine and broadcast warnings to the public, and when used to design risk reduction systems.

> Congress directed the LACPR effort to address a “Category 5” level of protection; however, the Saffir-Simpson Hurricane Scale is not sufficient for setting hurricane risk reduction design standards.
>
> Storm surge levels are significantly affected by storm size as well as storm intensity (Saffir-Simpson category), which changes the manner in which a storm must be specified for design purposes.
>
> Previously, it was believed that the Saffir-Simpson intensity scale dictated the potential surge levels that a storm could generate. It is now recognized that a small “Category 5” storm will generate a smaller surge than a large “Category 3” storm in coastal areas where the offshore slope is very small, such as along much of the Louisiana-Mississippi coastline.

A critical element of the risk analysis is to establish the standard for representative storms. Prior to Hurricane Katrina, the USACE, the National Oceanic and Atmospheric Administration (NOAA), and the National Weather Service utilized the Saffir-Simpson Hurricane Scale for categorizing hurricane strength. Up until then, this scaling system served the public as to the advisability of evacuation from areas where winds may prove dangerous to lives and property.

The Saffir-Simpson Hurricane Scale remains an effective part of the forecast warning system and an accurate predictor of hurricane wind damages; however, it is not an adequate tool in assessing storm surge heights. In many cases, and especially in coastal Louisiana, the greatest threat to lives and property and the environment from storms is the storm surge flooding. Therefore, the USACE has adopted a risk-based probabilistic approach to predicting and evaluating a range of possible hurricane storm surge events. Specifically, the LACPR effort addresses the range of frequencies from a 100-year to a 1000-year event, including the 400-year Katrina-like surge event.

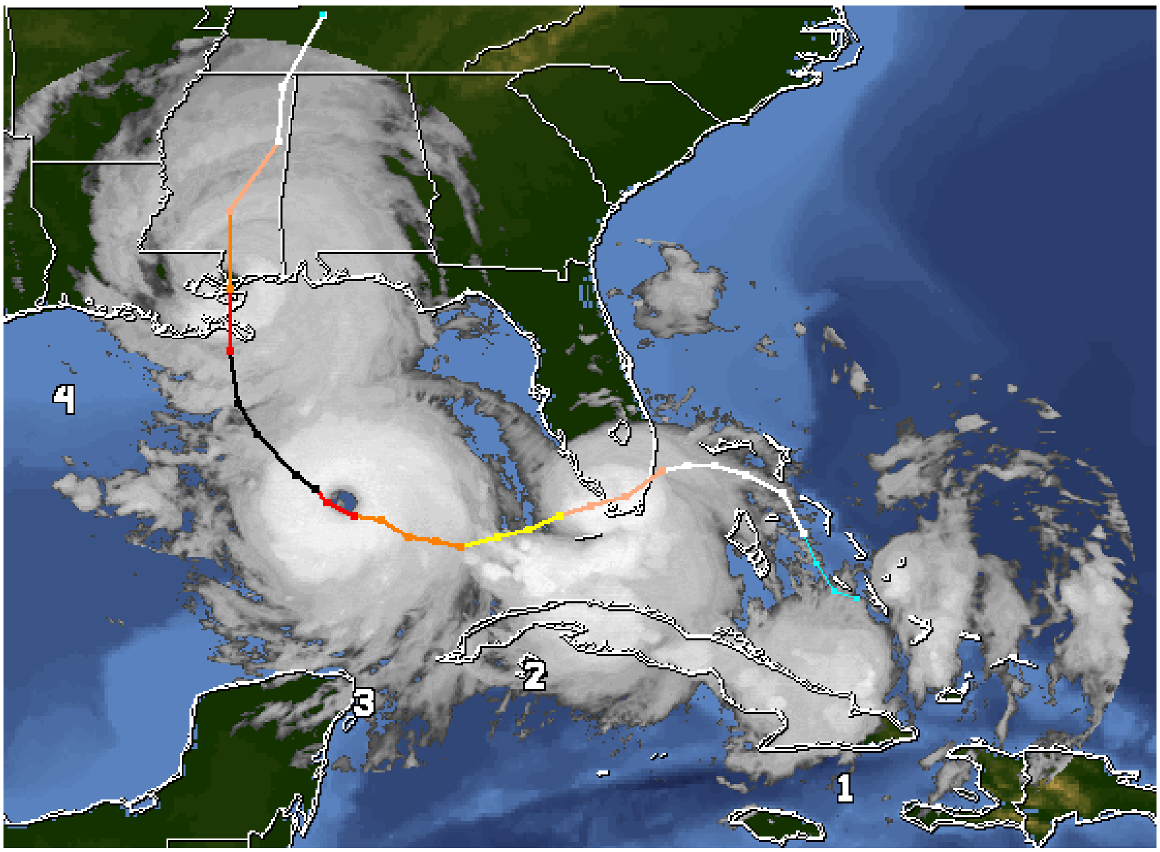
Myth 1 – All Hurricanes are Created Equal

One hurricane myth is that any storm of a certain category will be just like any other storm of the same category. As witnessed in Hurricane Katrina, lower category storms, based on the Saffir-Simpson Hurricane Scale, can produce higher storm surges than smaller but higher categorized storms. Camille, Audrey, Carla and Charley all had higher wind speeds at landfall than Katrina, yet Katrina produced at least five more feet of storm surge than even Camille, a Category 5 storm.

Hurricane Katrina produced unparalleled wave and storm surge conditions for the New Orleans vicinity. Hurricane Katrina was a very large Category 3 storm when it passed over the New

Orleans area on the morning of August 29, 2005. Twenty-four hours earlier this storm had been the largest Category 5 and most intense (in terms of central pressure) storm on record within the northern Gulf of Mexico (see **Figure 2-1** below). Due east of the Mississippi River Delta, a deepwater buoy recorded the highest significant wave height (55 feet) ever measured in the Gulf of Mexico. The large size of Katrina throughout its history, combined with the extreme waves generated during its most intense phase, enabled this storm to produce the largest storm surges (reliable observations up to 28 feet) that have ever been observed.

Figure 2-1. Time-lapsed satellite photo showing Hurricane Katrina's path and growth.



Source: National Oceanic and Atmospheric Administration

Table 2-1 shows where Hurricane Katrina's characteristics fall within the Saffir-Simpson Hurricane Scale (shaded blocks represent Hurricane Katrina). Note that based on three physical characteristics, wind speed, central pressure and surge height, Hurricane Katrina displayed attributes from three different categories on the Saffir-Simpson Hurricane Scale.

Table 2-1. How Hurricane Katrina fits within the Saffir-Simpson Hurricane Scale.

Scale Number (Category)	Winds (miles per hour)	Pressure (millibars)	Approximate Surge (feet)	Damage
1	74-95	980	4 to 5	Minor
2	96-110	965 – 979	6 to 8	Considerable
3	111 – 130	945 – 964	9 to 12	Extensive
4	131 - 155	920 - 944	13 to 18	Extreme
5	> 155	< 920	> 18	Catastrophic

Thus, it is important to consider a range of storm sizes in conjunction with a fixed “Category 5” intensity (millibars), in order to represent the actual range of conditions that a “Category 5” storm can generate. If the Maximum Possible Intensity for the Gulf of Mexico (880 millibars) is selected, and a number of different sized storms are simulated, the range of surge levels that might be associated with a “Category 5” storm will be effectively covered. The return periods for these surges will depend on the specific storms simulated, but can be expected to range from around 100 years to at least 1,000 years. This fact demonstrates the need to reevaluate storm classification in order to keep the public accurately informed of risk and is the approach used for LACPR to satisfy the directive by Congress to consider “Category 5” protection for the Louisiana coastal area.

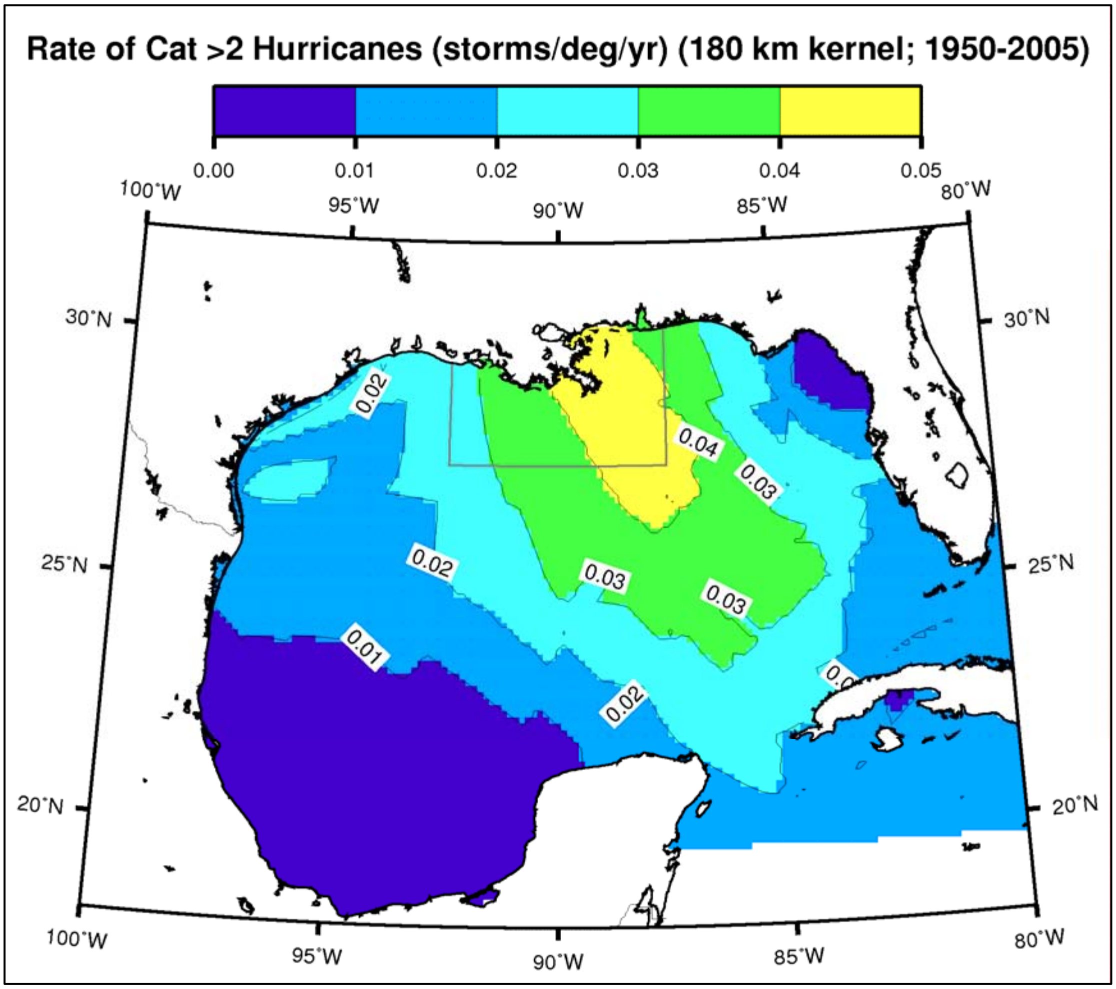
Myth 2 – All Areas of the Gulf Coast Have the Same Chance of Experiencing Powerful Hurricanes

Until recently, weather scientists believed that all areas along the Gulf Coast have an equal chance of being hit by a major hurricane or high storm surge. What has been determined since 2005 is that certain areas of the Gulf of Mexico are more likely to experience higher intensity storms.

While determining that not all hurricanes are the same, the IPET also concluded that relying solely on historic storms to help design risk reduction measures for future threats is inadequate. Using the characteristics of past storms to predict future storms, IPET, along with the American Society of Civil Engineers and the National Research Council, used advanced hydromodeling to create hypothetical storms and their paths that could potentially develop in the future.

Figure 2-2 shows the relatively higher probability of severe hurricane occurrence for southeastern Louisiana, Mississippi, and western Alabama relative to the probability of occurrence elsewhere along the Gulf of Mexico. For example, New Orleans, Louisiana is twice as likely as Galveston, Texas to be hit by a Category 2 or higher hurricane (a four percent chance versus a two percent chance in any one year). These probabilities were calculated based on the historical record from 1950 to 2005.

Figure 2-2. Rate of hurricanes greater than Category 2 by area within the Gulf of Mexico.



Source: Risk Engineering, Inc.
Note: “Kernel” refers to a measurement of water area, i.e. square kilometers.

Myth 3 – The 100-Year Storm Surge Will Only Occur Once Every 100 Years

A common public misconception is that the 100-year storm surge will only occur once every 100 years. Just as there is a 50 percent chance of getting heads each time a coin is flipped, but it is still possible to flip heads several times in a row, it is possible to experience the one percent storm surge in consecutive years.

The 100-year storm surge implies an annual probability of one percent. When considering the effect of storm surge over a 30-year mortgage life, the risk of experiencing a 100-year event is over 25 percent. Factoring in the average lifespan of a Louisiana resident—between 70 and 75—more than half the population living within the planning area could experience a catastrophic flood event. Over thousands of years, a one percent storm should occur, *on average*, once in 100 years. However, within a *given* period of 100 years, the 100-year storm actually has a 63 percent chance of occurring.

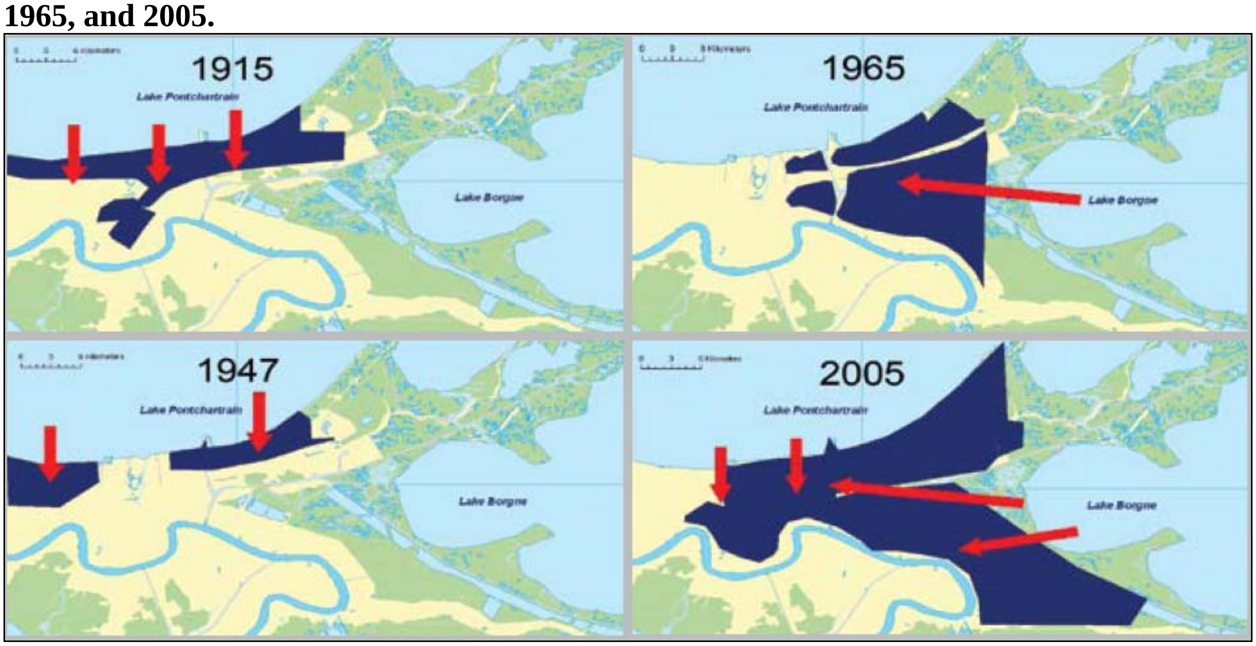
Hurricane Rita, computed to have produced a peak storm surge with an approximately 90-year return interval, is a close comparison to a 100-year storm based on size, intensity, and track. In contrast, Katrina has been estimated to have produced an approximately 400-year storm surge.

Proactive Risk Management and Communication

In addition to the threat imposed by natural forces, human decisions and policies contribute to the risk equation. In the absence of proactive communication of risk to residents, many adopt a false sense of safety, which becomes inherently more dangerous in the face of potential increases in storm intensity. No system is 100 percent effective at eliminating risk, and weaknesses in individual components can threaten the entire risk reduction system. Therefore, residual risks should be quantified and effectively communicated to the public and decision makers.

Flood risk management in the City of New Orleans and coastal communities through the 20th century generally was not founded on proactive approaches, but rather developed reactively in response to specific catastrophic floods. After each flood, modest investments were made in improved defenses that reduced the immediate risk of flooding. However, each investment in improved flood defenses prompted additional development in the partially protected flood plain and thus increased the number of people and structures at risk. This trend is demonstrated by the magnitude of losses in each of the four storm surge floods that affected New Orleans after 1900 (Grossi and Muir-Wood, 2006). **Figure 2-3** compares these historic flooding events (dark blue areas represent flooding).

Figure 2-3. Historical flooding in New Orleans due to hurricane storm surges in 1915, 1947, 1965, and 2005.



Source: Grossi and Muir-Wood, 2006.

In an environment where flood risk is increasing over time rather than remaining constant, as is the case of coastal Louisiana, once flood defense improvements are installed, the level of risk increases year after year. The LACPR effort attempts to assess true flood risk and to effectively communicate that risk to policy makers and to the general public so that informed decisions can be made.

Storm Modeling Overview

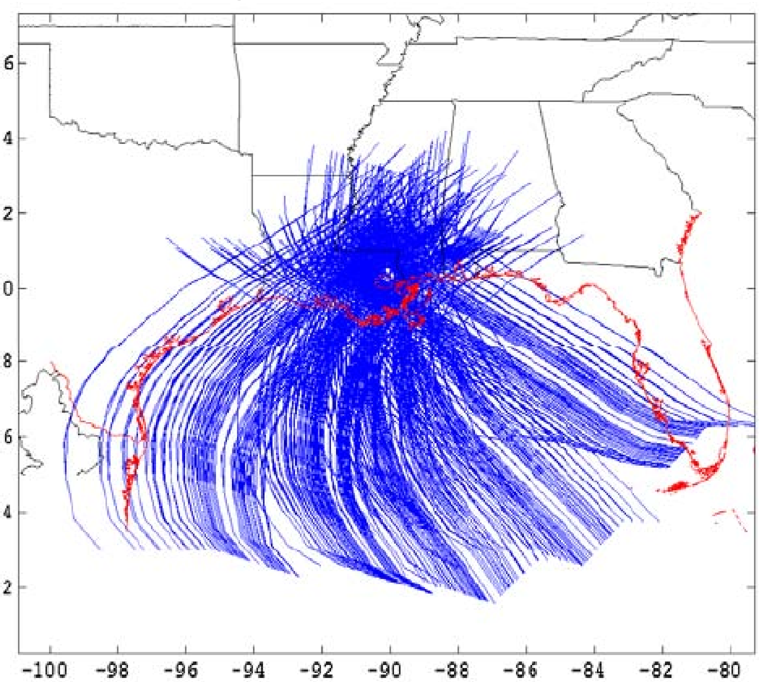
Prior to the hurricanes of 2005, no single model or set of models existed to meet the needs of the USACE for performing a risk-based assessment of storm inundation probability as has been done for LACPR. Therefore, a group of international, government, academic, and private sector scientists and engineers were assembled to develop a model that could simulate hurricane surge and wave elevations and show these in terms of return probabilities (i.e., 100-year, 400-year, 1000-year events, etc.). Details on the storm modeling approach can be found in the *Hydraulics and Hydrology Appendix*.

In assessing hurricane threats and risks the team employed advanced computer storm simulation software to evaluate a full range of hurricanes that could make landfall in coastal Louisiana. ADCIRC (ADvanced CIRCulation) is a state-of-the-art, physics-based computer model that can simulate a powerful storm once it forms in the Atlantic and bring it to its coastal landfall. The computer simulations allow planners to evaluate different storm tracks, landfall speeds, and wind fields. Coupling this program with wave generation software and other tools enables technical planners to develop assessments of hurricane impacts which can then be used to evaluate different risk reduction strategies and alternatives.

For the LACPR modeling effort, the ADCIRC program was run on two supercomputers; it would take 4,000 desktop computers linked together to equal the computing power available in each supercomputer. In terms of human labor, it would take 1,000 scientists 535 years of working around the clock to do the same computations that one of these machines can do in one second. This use of advanced technology has vastly improved the ability of the USACE to evaluate hurricane threats along the northern Gulf Coast.

The computer simulation models reflect central pressure, radius of maximum wind speed, storm forward speed, storm landfall location, and the angle of the storm track relative to the coast. The models are capable of fluctuating storm strength as a storm approaches the coast in order to estimate the surge at the coast. This is important because storms often decay as they make landfall. A sufficient number of different computer simulated storms had to be run on different tracks to develop a statistically significant database. A total of 304 storms (152 in the east side of the State and 152 in the west side) were run for the entire Louisiana coast as shown in **Figure 2-4**.

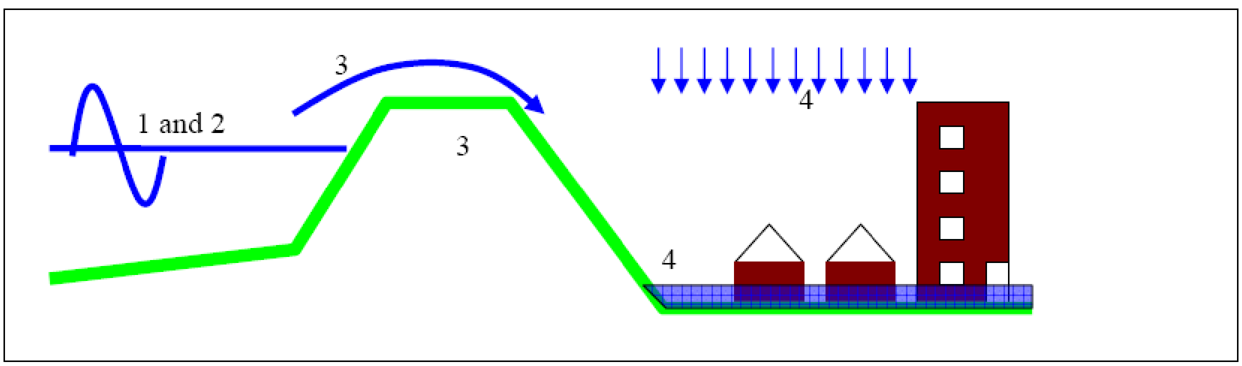
Figure 2-4. Simulated storm paths.



From running all these storms, over three million data points were analyzed to derive the surge and wave heights across the Louisiana coast using the Joint Probability Method-Optimum Sampling (JPM-OS) of all grid points in the ADCIRC domain. The JPM-OS analysis uses the maximum stage computed at each of the grid points simulated in ADCIRC to compute the stage frequency at each of the grid points. The planning area contains thousands of stage frequencies from which statistical surfaces can be prepared.

After predicting storm surge and waves as described above, the team designed a series of levees at the 100-year, 400-year, and 1000-year design level and calculated quantities of water that would theoretically overtop the levees under various conditions including 100-year, 400-year, 1000-year and 2000-year surge events accompanied by the 10-year rainfall event. **Figure 2-5** provides an illustration of the step-wise modeling approach to capturing the hydraulic processes within the LACPR effort, which are simplified as (1) surge levels (2) wave run-up (3) levee overtopping and (4) interior flooding from overtopping and rainfall.

Figure 2-5. Schematic overview of the step-wise approach in the hydraulic analysis.



The later half of the step-wise modeling approach employs the development of hydraulic relationships for the determination of interior flooding of alternative plans due to acceptable levee overtopping and rainfall volumes. Stage-storage relationships, relationships that effectively approximate flood levels based on these incoming volumes, are used to assess levels of damage and residual risk for various alternative plans. This analysis is critical to the evaluation of alternatives in a risk-informed decision framework.

The academic community has reviewed this modeling approach and U.S. government agencies have adopted it as a systems approach for calculating the storm-surge probabilities at different locations. The hydromodeling techniques used for LACPR represent a significant advancement in surge and wave modeling and will be executed for years to come.

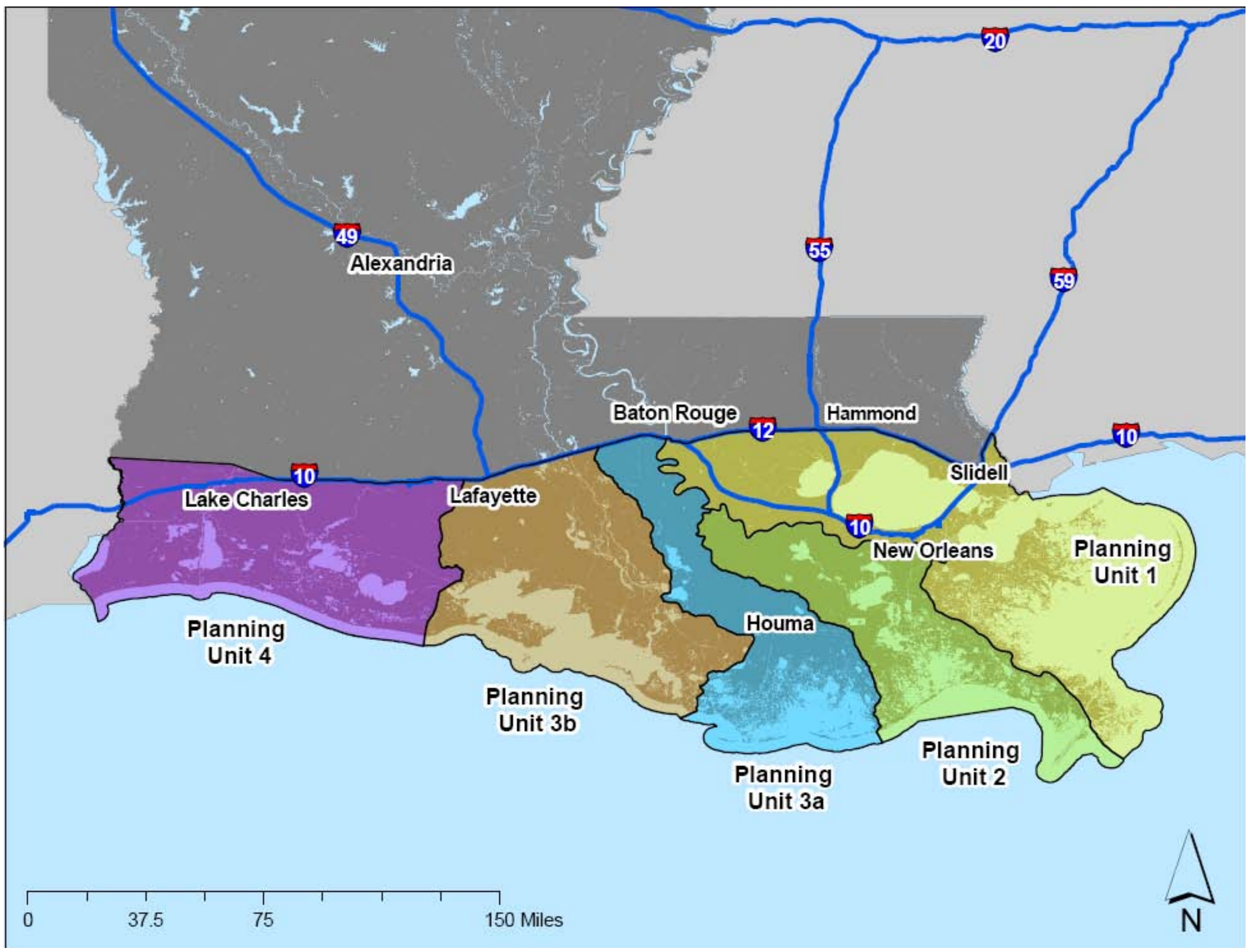
Section 3. Planning Considerations

The following sections provide an overview of the problems in the South Louisiana area, the goals and objectives set out to solve those problems, and the assumptions and methodologies used to perform the LACPR technical evaluation.

LACPR Planning Area and Planning Units

The LACPR planning area (see **Figure 3-1** below) stretches across Louisiana's coast, including offshore islands, from the Pearl River on the Mississippi border to the Sabine River on the Texas border. The northern planning area boundary roughly follows Interstates 10 and 12 since hurricane surges are not expected north of these physical boundaries. Based on 2000 U.S. Census Bureau data, the planning area contains approximately 2.4 million people.

Figure 3-1. Map showing LACPR planning area and planning units.



Two coastal wetland-dominated ecosystems comprise the planning area, the Deltaic Plain and the closely linked Chenier Plain. The Deltaic Plain contains ecologically important estuaries fronted by numerous barrier islands, including the Chandeleur Islands, Barataria Basin Barrier Islands, and Terrebonne Basin Barrier Islands. The Chenier Plain contains important diverse wildlife and fisheries habitat, extending from Freshwater Bayou to Louisiana's western border with Texas, and is characterized by several large lakes, marshes, cheniers (oak ridges), and coastal beaches.

The Deltaic and Chenier Plains have been further divided based on hydrologic basins and watersheds as previously established in other efforts such as the Louisiana Coastal Area study, Coast 2050 plan, and recent State Master Plan. The resulting five LACPR planning units are similarly defined as four sub-provinces in the Louisiana Coastal Area (LCA) study and four corresponding regions in the Coast 2050 plan; however, for LACPR and the State Master Plan, Sub-province or Region 3 was divided into Planning Units 3a and 3b. The team added a boundary between Planning Units 3a and 3b because system disruptions, as well as the opportunities for restoration, are different in these areas.

The five LACPR planning units are listed below:

- **Planning Unit 1 – Lake Pontchartrain Basin**, or the area east of the Mississippi River. Planning Unit 1 includes a population of about one million. The major portion of greater New Orleans is located within the planning unit.
- **Planning Unit 2 – Barataria Basin**, or the area from the Mississippi River west to Bayou Lafourche. Planning Unit 2 contains a population of about 300,000, including a portion of greater New Orleans.
- **Planning Unit 3a – Eastern Terrebonne Basin**, or the area west of Bayou Lafourche to Bayou de West. Planning Unit 3a includes a population of about 249,000.
- **Planning Unit 3b - Atchafalaya Influence Area**, or the area west of Bayou de West to Freshwater Bayou. Planning Unit 3b includes a population of about 350,000.
- **Planning Unit 4 – Chenier Plain**, or the area west of Freshwater Bayou to the Sabine River. Planning Unit 4 includes a population of about 250,000.

For detailed economic analyses, the planning units were further divided into approximately 900 planning subunits. Planning Units 1 and 2 consist of approximately 200 subunits and Planning Units 3a, 3b, and 4 consist of approximately 700 subunits.

Assets at Risk: What's at Stake?

As coastal wetland loss continues, the threat of storm surge to populated areas increases. Impacts of major storms on communities, natural resources, transportation systems, industries, and strategic economic resources are the subject of growing concern. Even if the populated areas can be made safer through improvements to existing hurricane risk reduction measures, the losses of coastal areas outside of the risk reduction systems pose an increasing threat to the economic and environmental sustainability of the region. When investments in residential, nonresidential and transportation infrastructure are totaled, the capital investment in the LACPR planning area adds up to well over $100 billion and will continue to increase over time (see **Table 3-1**).

Table 3-1. Asset values for the LACPR planning area.

Year	Residential	Nonresidential	Roads	Railroads	Total
	($Billions in US, 2006 price level)				
2010	65.2	15.5	29.8	0.8	111.3
2075	103.8	25.7	29.8	0.8	160.1

Source: USACE GIS Economic Application Database. Note: Residential and nonresidential assets include structures (without contents) and vehicles. Roads include highways and streets. Pipelines are not included. Projections assume high employment growth and dispersed land use. Increased values for roads and railroads in the year 2075 were not projected.

Communities and Cultural Resources at Risk

Communities across South Louisiana are subject to inundation by hurricane storm surges. The coastal region contains 55 percent of the State's population; over 2.4 million people according to a January 2006 Post-Disaster Population Estimates by the Louisiana Department of Health and Hospitals Bureau of Primary Care and Rural Health. Major population centers at risk from hurricane surges include the greater metropolitan area of New Orleans, the Houma – Thibodaux area, and the Lake Charles metropolitan area.

Communities of unique heritage can be found nestled within urban areas and on the rural landscape. The people who reside within this region derive from diverse cultural backgrounds and form numerous ethnic groups including Creole, Cajun, African American, French, Spanish, Native American, South American, Yugoslavian, Isleño (Spanish speaking migrants from the Canary Islands), Filipino, Italian, German, Chinese, and Vietnamese, among others. In addition, the coastal wetlands of Louisiana have been a setting for diverse cultural developments. For example, sustainable fishing communities of Native American, Isleño, Acadian and Vietnamese heritage found within the coastal parishes and such communities are becoming increasingly rare within the Nation.

Cultural assets, such as prehistoric and historic archaeological sites, historic buildings, and historic districts are located throughout the region. The contribution of many of these assets, individually or taken together in groups, is invaluable in defining the character of South Louisiana. The architecture of public, religious, commercial, and residential buildings within the New Orleans and surrounding parishes reflect the City's historic development and the people and cultures that built the City. Vernacular architecture found in coastal and pastoral communities reflects rural lifeways, contributes to the regional landscape, and creates a sense of place.

Coastal subsidence, wetland losses, and relative sea level rise (the increase in the difference between ground elevations and mean sea level elevations) make these coastal communities increasingly vulnerable to inundation from hurricane-induced storm surges. As these coastal changes continue, inundation could occur more frequently and at greater depths than experienced in recent history. Communities are at risk of dispersion and disintegration following inundation events. The damage to or loss of archaeological/historic resources, parks and neighborhoods could lead to the loss of individual and community connection to a particular geographic place or location. Taken together, these outcomes could lead to a net loss of cultural diversity in South Louisiana. Storm-related disruptions to the populations and work force and their availability impact the entire economy of South Louisiana and portions of the national and international economies.

Natural Resources at Risk

The Louisiana coastal plain contains one of the largest expanses of coastal wetlands in the contiguous U.S. Wetlands erosion in the State accounts for 90 percent of the total coastal marsh loss in the Nation. The coastal wetlands contain an extraordinary diversity of coastal habitats, ranging from narrow natural levee and beach ridges to expanses of forested swamps and freshwater, intermediate, brackish, and saline marshes. Approximately 70 percent of all waterfowl that migrate through the U.S. use the Mississippi and Central flyways. With more than five million birds wintering in Louisiana, the Louisiana coastal wetlands are crucial habitat to these birds, as well as to neotropical migratory songbirds and other avian species that use them as crucial stopover habitat. Additionally, coastal Louisiana provides crucial nesting habitat for many species of water birds, such as the brown pelican. The coastal wetlands of Louisiana are significant on a national level. The habitats, serve as support to thousands of birds, fish, and other species, making the coastal wetlands of Louisiana among the Nation's most productive and important natural assets.

Transportation Systems at Risk

Transportation systems in South Louisiana include deep- and shallow-draft navigation, road, rail and air. These systems are critical to regional, national, and international trade. The Mississippi River and channels leading to the other major coastal ports of Louisiana are vulnerable to excessive siltation from surges and from disruption by ships being damaged, grounded or sunk. The Gulf Intracoastal Waterway (GIWW) runs across the State through the coastal wetlands. In its current environment, the GIWW is subject to blockage from excessive storm-induced siltation and stranded or sunken tows. Gate and lock structures could be compromised if rammed by uncontrolled craft. Similarly, flooding and storm surges could destroy runways, railways, and highways, or make them impassible.

Industries at Risk

Louisiana has a significant role in the Nation's economic health through industries including oil and gas, agriculture, aquaculture, river freight, and tourism. Most of these industries are concentrated in the coastal areas subject to flooding.

Louisiana is also an exporter of sulfur, salt, forest products, agricultural products, chemicals, and seafood. Coastal Louisiana provides an integral national-security function by supporting energy independence, balance of trade, defense construction, and the efficient and effective transportation of commodities.

Ports - Economic facilities in South Louisiana supporting the oil and gas industry include seven deep-water ports, the majority of which are along the Mississippi River from its mouth to Baton Rouge. The others are placed along the Gulf of Mexico region. This network of port facilities forms a critical hub for international trade, representing the largest deep-draft shipping complex in the world. The combination of waterborne commerce, trunkline railroads, highways, and trucking connections accommodate the movement of grain, petroleum, natural gas, and a wide range of other products important to both national and international commerce.

Petroleum Industry - Oil, gas, and petrochemicals represent Louisiana's largest industry (LCA, 2004). South Louisiana ranks second in the Nation for natural gas and fourth in the Nation for crude oil production (U.S. Department of Energy, 2007). The domestic energy sector is heavily dependent on oil and gas exploration, production, and petrochemical refining along the coast of Louisiana. The State also serves as entry point for critical foreign oil imports. In addition, Louisiana is home to many strategically important energy production and distribution facilities. Of this infrastructure, refineries themselves are the most vulnerable to flooding.

Commercial Fisheries - The National Marine Fisheries Service reports that 2004 fish and shellfish landings in Louisiana represented approximately 11 percent of the U.S. total. That same year, Louisiana commercial landings exceeded one billion pounds with a dockside value of approximately $275 million. Three out of the top ten commercial fishery ports in terms of pounds are located in coastal Louisiana. Fisheries are impacted by coastal land loss and the fishing force and fleet are vulnerable to major storm events.

Tourism - The Louisiana Travel Promotion Association has reported that tourism is the second largest industry in Louisiana, generating $9 billion in expenditures, attracting over 21 million visitors annually, and providing employment for approximately 120,000 residents. Louisiana is home to many attractions such as the French Quarter, plantations, Cajun country, and outdoor activities. The Louisiana Department of Wildlife and Fisheries reported in 2003 that Louisiana supported a sport hunting industry of $599 million and recreational fishing industry of $895 million.

Medical Industry - Two of the State's three medical schools are located in New Orleans. Approximately 45 percent of the State's outpatient health care services are located in the New Orleans metropolitan area, along with numerous hospitals and nursing care facilities.

Shipbuilding - According to the 2002 U.S. Economic Census Report, more than 100 ship and boat building companies were located in Louisiana, employing 13,859 people with payrolls totaling more than $425 million. Total shipments exceeded $1.9 billion, including more than $900 million by manufacturing firms. The companies range in size from small businesses with one or two employees to large national defense corporations.

Goals

The overall goals of LACPR are presented as follows:

- Conduct a comprehensive hurricane risk reduction analysis and design to develop and present a full range of flood damage reduction, coastal restoration, and hurricane risk reduction measures for South Louisiana.
- Evaluate risk reduction for a range of storms from the 100-year to the 1000-year storm event (which encompasses a range of "Category 5" events) within the planning area.
- Conduct a transparent planning process to include independent technical review and external peer review.
- Engage the State of Louisiana, State and Federal agencies, stakeholders, and the general public as active partners in the planning process.

Problem Statement

The nature of risk to the planning area is identified in the following problem statement:

> The people, economy, environment, and culture of South Louisiana, as well as the Nation, are at risk from severe and catastrophic hurricane storm events as manifested by:
>
> - Increasing risk to people and property from catastrophic hurricane storm events.
> - Increasing vulnerability of coastal communities to inundation from hurricane induced storm damages due to coastal subsidence, wetland losses, and sea level rise.
> - National and regional economic losses from hurricane flooding to residential, public, industrial, and commercial infrastructure/assets.
> - Losses to high levels of productivity and resilience of South Louisiana coastal ecosystem due to natural conditions and coastal storm disturbances.
> - Risks to historic properties and traditional cultures and their ties and relationships to the natural environment due to catastrophic hurricane storm events.

The risks associated with the problem can rarely be eliminated or entirely prevented. Thus, residual risks that will remain after plan implementation must be considered.

Objectives

The following planning objectives were established to help solve the problems defined above and to develop the full range of flood damage reduction, coastal restoration, and hurricane risk reduction measures:

- Reduce risk to public health and safety from catastrophic storm inundation.
- Reduce damages from catastrophic storm inundation.
- Promote a sustainable coastal ecosystem.
- Restore and sustain diverse fish and wildlife habitats.
- Sustain the unique heritage of coastal Louisiana by protecting historic sites and supporting traditional cultures.

Assumptions, Guidelines, and Constraints

In order to conduct the analysis, the LACPR team had to set certain assumptions and guidelines. The following is a brief summary of those assumptions and guidelines used during the LACPR analysis. More detailed explanations follow in the remaining report sections.

General

- Required to develop new water resources project development methodology to support plan formulation, evaluation, comparison and recommendation, including:
  - Advanced modeling to quantify system performance;

  - Scenario-based analysis (multiple without project futures);
  - Objective performance evaluation (metrics to evaluate achievement of coast wide objectives);
  - Multi-criteria decision analysis (value-based ranking of alternatives); and
  - A risk-informed decision process.
- Project assessments and performance evaluations conducted are for relative plan comparison and not intended to support specific project authorization, detailed engineering design, or construction).
- The LACPR analysis does not take into account local actions (e.g., land use restrictions, change in building codes, etc.).
- Louisiana's State Master Plan provides overarching vision for LACPR.

<u>Baseline Conditions - Without-Project/No Action</u>

Existing Projects:

- The without-project conditions include the following projects:
  - Federally-authorized navigation, flood risk management, hurricane risk reduction, and environmental restoration projects in the planning area, *except for* projects recently authorized by WRDA 2007, i.e. Morganza to the Gulf hurricane protection and LCA ecosystem restoration projects (these are considered as part of the with-project conditions).
  - Non-Federal levees at existing design levels.
- The without-project conditions will not change regardless of whether funds are sufficient to complete the authorized projects.
- Improvements to bring the West Bank and Vicinity and the Lake Pontchartrain and Vicinity Projects to a 100-year design level are anticipated to be completed by 2011.

<u>Future Without-Project Conditions (Future Degraded)</u>

- Without action, the coastal landscape will continue to degrade.
- Authorized elevation for existing/improved levee projects is assumed to be maintained.
- Level of risk reduction provided by existing levee systems is assumed to degrade over time (worst-case scenario).
- Based on four future scenarios (including consideration of two increased levels of relative sea level rise and two redevelopment rates and land use assumptions).
- Alternative plans are compared to the no action plan to measure relative plan performance.

<u>Future With-Project Conditions (Future Maintained)</u>

- Coastal restoration is included as a fundamental building block for all alternatives.
- The goal is to sustain (maintain) the existing coastal landscape.
- Project performance of existing, improved and proposed levees assumed to be maintained (future costs/additional construction lifts incurred to maintain performance) over the period of analysis.

Period of Analysis

- A 50-year period of analysis from 2025 to 2075 was used to evaluate all alternatives.
- Year 2025 was chosen as the common base year for comparison of alternatives since it generally represents the end of the implementation period for most alternatives considered.

Plan Formulation Process

- Alternatives were developed by planning unit for better manageability.
- All with-project conditions include a coastal restoration component to sustain the existing coastal landscape.
- Nonstructural, structural, and comprehensive alternatives were formulated at the 100-year, 400-year and 1000-year design levels.
- The 400-year and 1000-year design represents low and high "Category 5" risk reduction.
- Alternatives were developed using three concurrent plan development/formulation activities (coastal, nonstructural and structural).
- Alternatives fall into four with-project categories (listed in bold below), plus the no action alternative.
  - **Coastal Restoration Measures and Alternatives**
    - Each coastal restoration alternative consists of hundreds of individual measures.
    - Coastal restoration alternatives were screened based on projected performance to achieve sustaining existing landscape over a 100-year period (although metrics are based on performance at 2075 for consistency with overall period of analysis).
    - Plans developed as set of measures to achieve goal (no incremental analysis of coastal measures performed).
  - **Nonstructural Measures and Alternatives**
    - Nonstructural plan components were developed based on decision criteria for high velocity flow areas (buyouts) and depth of inundation (buyouts and raising assets in place).
    - Stand alone nonstructural alternatives as well as complementary nonstructural components to structural alternatives have been formulated.
    - Nonstructural measures/components are additive to structural measures.
    - Nonstructural plans are presented as voluntary participation; however, associated risk reduction for nonstructural alternatives is assumed for this stage of analysis to be based on 100 percent participation.
  - **Structural Measures and Alternatives**
    - Levees and structures are designed based on a 90 percent confidence limit (consistent with current USACE hurricane system design work).
    - Tiered screening process used to reduce possible structural measures and alignments to a more manageable number for further evaluation and consideration across a range of stakeholder interests.

    - **Comprehensive Alternatives** provide a comparable level of risk reduction (design level) to all areas impacted by hurricane surge by including each of the three types of measures (coastal, nonstructural and structural). Complementary nonstructural measures are used to complement structural measures.

Evaluation Process

- Each alternative was evaluated for a range of storm events from a 10-year rainfall event to a 2000-year hurricane surge event.
- Hydromodeling and economic results are based on three confidence limits related to the uncertainty associated with water level data.
- Each alternative was evaluated for the four future scenarios.
- Each alternative was evaluated for 14 metrics across a range of objectives.
- The fiscal year 2007 discount rate of 0.04875 applies to the LACPR analysis.
- A representative coastal landscape from each planning unit has been included with nonstructural, structural and comprehensive alternatives for further evaluation.
- Comparison of the no action alternative and the future with-project condition (maintained coast) measures risk reduction attributed to coastal features/alternatives.
- Beyond the evaluation process described above, additional sensitivity analysis will be performed.
- **Nonstructural Evaluation**
    - The nonstructural analysis assumes that all new development, during the reconstruction post-2005 hurricanes, conforms to base floor elevations established for compliance with the National Flood Insurance Program. Therefore, if a nonstructural measure proposes a level of risk reduction greater than the 100-year level, only the cost of the height increment above the 100-year was included as an economic cost of raising-in-place for future growth.
    - For consistency, relocation assistance is included as a cost component of the nonstructural buyout measures.
    - Nonstructural measures are expected to be implemented incrementally and will accrue pre-base year benefits.

Decision Process

- Stakeholders and decision makers will continue to be engaged through a multi-criteria decision analysis process, which will be used to identify comprehensive plans by planning unit.
- Multiple rankings will be developed based on stakeholder values (weighting) for metrics.
- A multi-objective optimization process will be used to develop the coastal system across all planning units.

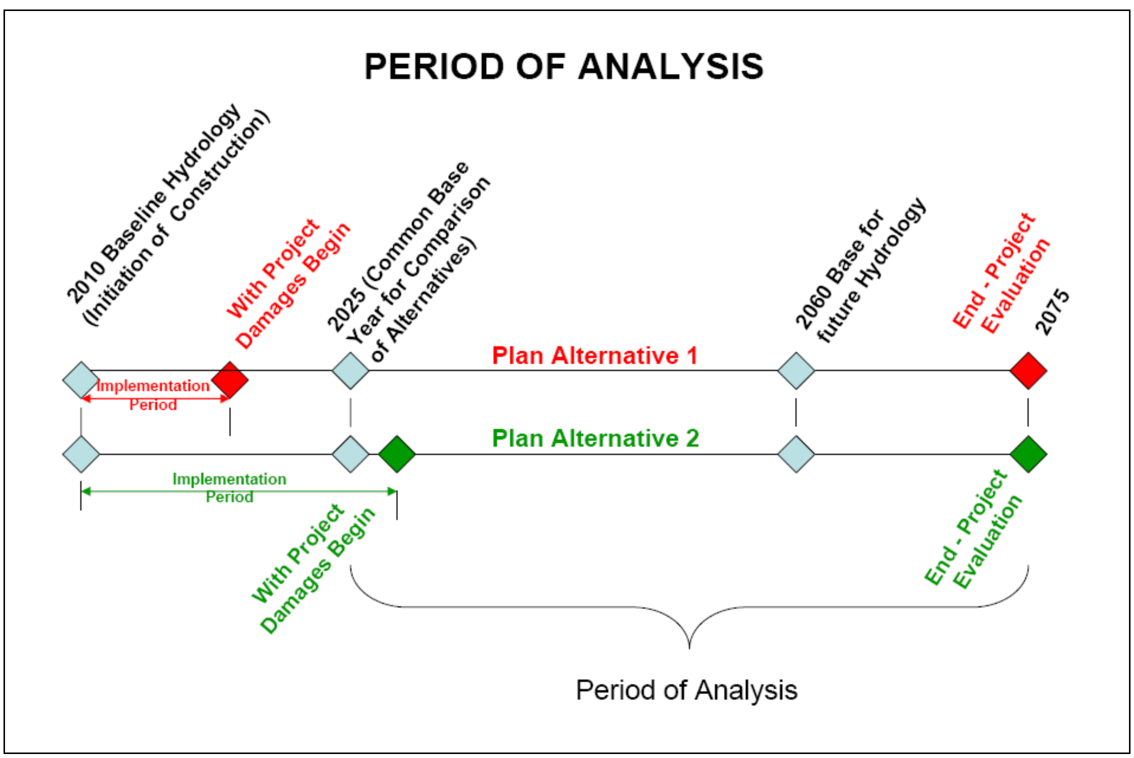
Period of Analysis

The period of analysis is the time horizon for which project benefits, deferred construction costs, and operation, maintenance, repair, rehabilitation, and replacement costs are analyzed. Project benefits and costs must be compared at a common point in time. Therefore, in cases where alternatives have different implementation periods, a common year, or base year, is established. Costs and benefits are compounded or discounted to that base year.

Year 2025 generally represents the end of the implementation period, or initial construction period, for most alternatives considered. Since the initial construction period for alternatives ranges from six to 16 years, the end date of a specific period such as 50 years would end at different years (ranging from 2065 to 2075). For this reason, the damages (benefits) and costs were extended to the year 2075 to ensure that each alternative had at least a 50-year period of analysis.

Figure 3-2 illustrates how two hypothetical alternatives (Plan Alternative 1 and Plan Alternative 2) of differing implementation periods are compared economically. The "implementation period" is the number of years to construct the plan after which benefits can be expected. For staged construction, the implementation period is the time needed to install the first phase. The common base year has been selected as the year 2025 with the period of analysis extending through the year 2075. In the illustration, Plan Alternative 1 has an implementation period terminating before the common base year – just the opposite of Plan Alternative 2.

Figure 3-2. Hypothetical period of analysis for plan alternatives.



Baseline hydrology is based on the year 2010 which represented the assumed completion of the authorized 100-year project for the New Orleans area at the time of analysis (current estimated completion is in 2011). The future hydrology developed for a degraded coastal landscape is based on the year 2060 consistent with the 50-year period evaluated by Coastal Louisiana Ecosystem Assessment and Restoration (CLEAR) modeling.

For the purposes of screening coastal restoration alternatives, a 100-year period was used. The reason a longer period was used in this case was that some of the coastal alternatives perform well after 50 years but poorly after 100 years. The environmental goal to sustain the existing landscape is measured at the end of a 100-year period in compliance with USACE Principles and Guidelines, which states that “appropriate consideration should be given to environmental factors that extend beyond the period of analysis.” Once the coastal alternatives were screened, each remaining alternative was then evaluated for performance in year 2075.

Section 4. Baseline Conditions

The baseline conditions are the no-action conditions assuming none of the LACPR alternatives are implemented. The baseline conditions include outputs of the hydromodeling analysis, which statistically predict the hurricane threat; an inventory of economic and environmental assets; and descriptions of existing projects designed to reduce risk to those assets. The baseline conditions have been evaluated at two points in time—now and in the future—as explained in the *Period of Analysis* section above. The inventory of existing and future conditions is contained within an extensive GIS database, which can be queried down to the census-block level.

Existing Hurricane Risk Reduction Projects

The following sections describe existing hurricane risk reduction projects and explain which projects were included in the LACPR baseline conditions. In general, the baseline conditions assume completion of Federally-authorized navigation, flood risk management, hurricane risk reduction, and environmental restoration projects in the planning area. The baseline conditions also include non-Federal levees at existing design levels.

2007 Water Resources Development Act

Although the Water Resources Development Act 2007 recently authorized the following projects, they are not included in the baseline conditions since they were not authorized at the time the analysis was conducted:

- Louisiana Coastal Area projects,
- Coastal Impact Assistance Program projects, and
- Morganza to the Gulf project.

Many or all features of the above projects, however, are included in the with-project conditions in various alternatives.

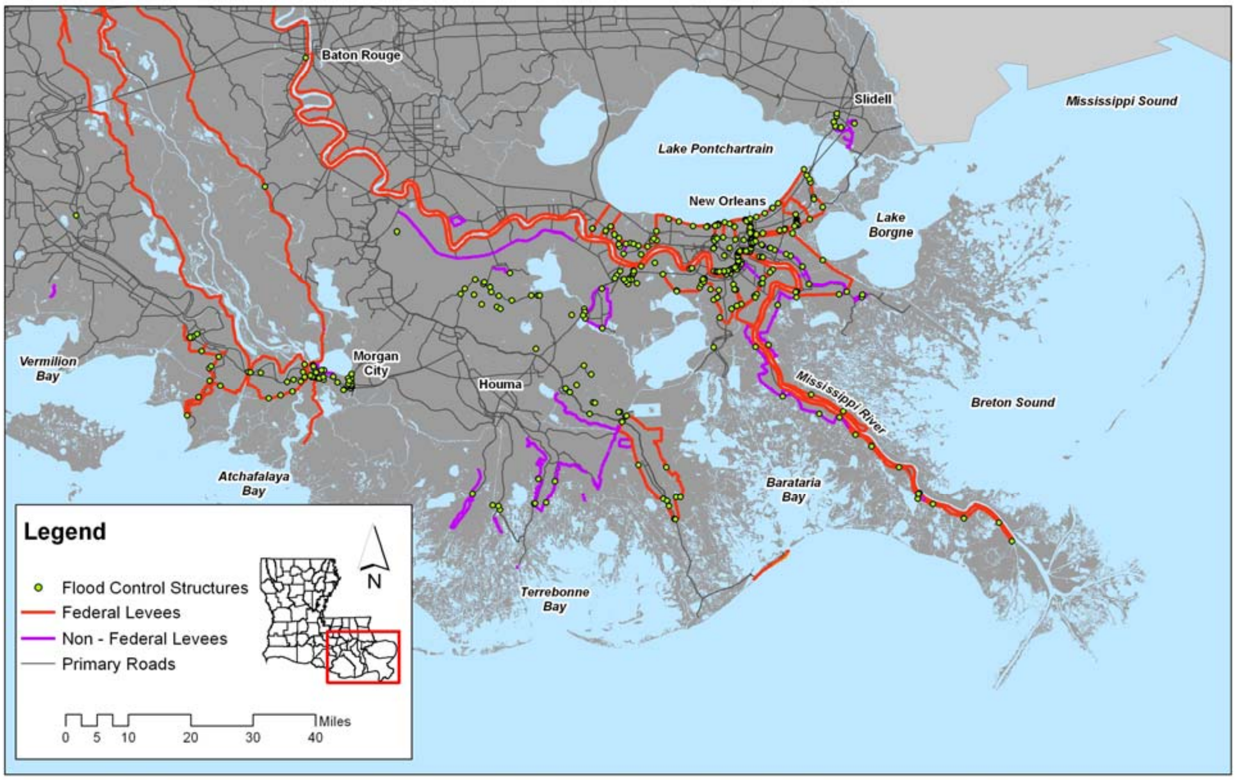
Emergency Supplemental Improvements for New Orleans

For New Orleans, the baseline conditions assume that improvements to the hurricane risk reduction system as authorized in Public Laws 109-148, 109-234, and 110-28 are in place. These laws provided funds to raise levee heights or otherwise enhance the West Bank and Vicinity and the Lake Pontchartrain and Vicinity projects to a 100-year design level. Implementation of the 100-year standard will be accomplished through improvements to levees, floodwalls, armoring, and associated structures in Jefferson, Orleans, portions of Plaquemines, St. Charles, and St. Bernard Parishes. Improvements are anticipated to be completed by 2011. Appropriations were also provided to accelerate completion of previously authorized hurricane and storm damage reduction and flood risk management projects in South Louisiana. For the purpose of this analysis, the baseline conditions assume that funds provided by these laws are sufficient to complete the authorized improvements.

Hurricane Risk Reduction and Flood Control Projects and Studies

Figure 4-1 shows the locations of existing Federal and non-Federal levees as well as existing flood control structures in Planning Units 1, 2, 3a, and part of Planning Unit 3b. The western portion of Planning Unit 3b and Planning Unit 4 do not contain any significant existing levees or hurricane flood control structures.

Figure 4-1. Existing Federal levees, non-Federal levees, and flood control structures.



The hydromodeling effort captured local (non-Federal) levees for the with- and without-project conditions through available LIDAR information reflecting pre-Katrina and Rita design levels. These design levels (although providing relatively low levels of risk reduction) have been assumed to be maintained at the current levels for the LACPR evaluation. In addition, some of the local levees have been restored by the USACE in response to emergency restoration efforts after Katrina, e.g. the St. Bernard Parish back levee was restored to an elevation of 10ft. The LACPR base condition reflects these repairs.

Table 4-1 and **Figure 4-2** display major existing USACE hurricane and flood control projects and studies by individual project or study name. Section 205 projects and studies are not shown in the table or on the map.

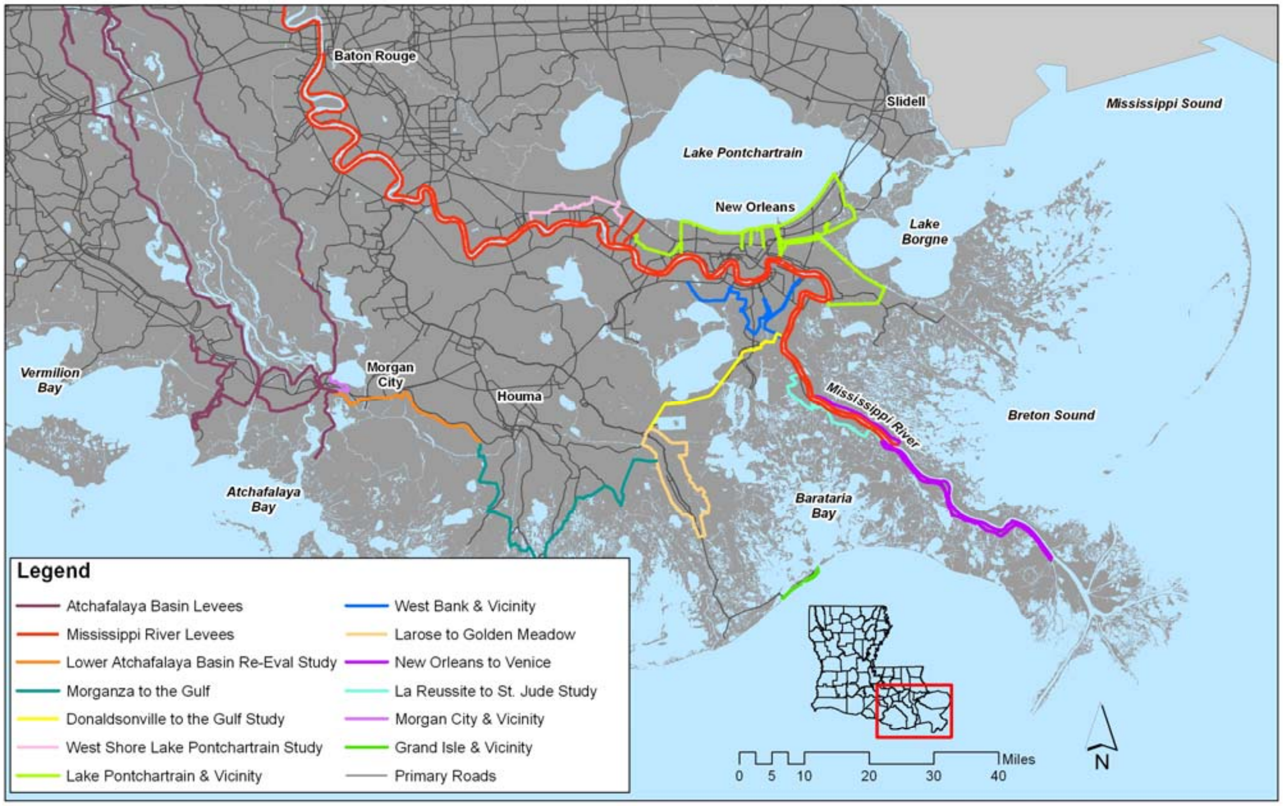
These projects and studies have evolved over different periods of time and are at various stages of completion. The LACPR analysis considers all authorized projects as part of its baseline condition, except for those recently authorized under the Water Resource Development Act as described above. Studies are evaluated as components of the overall LACPR comprehensive system.

Table 4-1. Major USACE hurricane and flood risk reduction projects and studies.

Common Project Name	Design Standard	Status
Lake Pontchartrain and Vicinity*	Standard Project Hurricane/ 100-year design	Construction phase
West Bank and Vicinity*	Standard Project Hurricane/ 100-year design	Construction phase
New Orleans to Venice	100-year design	Construction phase
Larose to Golden Meadow	100-year design	Construction phase
Morganza to the Gulf	100-year design	Authorized by WRDA 2007; not yet appropriated
Grand Isle and Vicinity	50-year design	Construction phase
Morgan City and Vicinity	Standard Project Hurricane	Morgan City area was deferred in 1987 and the Franklin area was de-authorized in 1997.
Mississippi River Levees	Mississippi River and Tributaries Project Design Flood	Construction phase
Atchafalaya Basin Levees	Mississippi River and Tributaries Project Design Flood	Construction phase
Common Study Name	**Design Standard***	**Status**
West Shore Lake Pontchartrain Study	To be determined	Feasibility phase
Southwest Coastal Louisiana Feasibility Study**	To be determined	Feasibility Cost Share Agreement currently being negotiated with the State of Louisiana.
Donaldsonville to the Gulf Study	To be determined	Feasibility phase
La Reussite to St. Jude Study (would be part of New Orleans to Venice project)	100-year design	Revised decision report needed
Lower Atchafalaya Basin Reevaluation Study	Mississippi River and Tributaries Project Design Flood	Study phase

Notes:
See Glossary for explanation of design standards.
*Originally authorized for Standard Project Hurricane; however, Public Laws 109-148, 109-234, and 110-28 authorize improvements to reach the 100-year design.
**Not shown on map.

Figure 4-2. Existing hurricane and flood risk reduction projects and studies.



State of Louisiana's Emergency Alert System and Evacuation Planning

The Governor's Office of Homeland Security and Emergency Preparedness (GOHSEP) ensures that the State of Louisiana is prepared to respond to, and recover from, all natural and man-made emergencies. GOHSEP provides the leadership and support to reduce the loss of life and property through an all-hazards emergency management program of prevention, mitigation, preparedness, response and recovery. GOHSEP has enabled the Integrated Public Alert and Warning System (IPAWS) which is administered by FEMA for the Department of Homeland Security and addresses the mandate and vision of Executive Order 13407 to create a comprehensive and modern public alert and warning system. The IPAWS components and pilot project work in conjunction with GOHSEP's existing Emergency Alert System. IPAWS will help provide critical and timely information alerts and warning that will save lives and property not only to governmental agencies, but to the general public, business, schools and other groups. This program is independent of LACPR but is an essential element of any risk reduction plans.

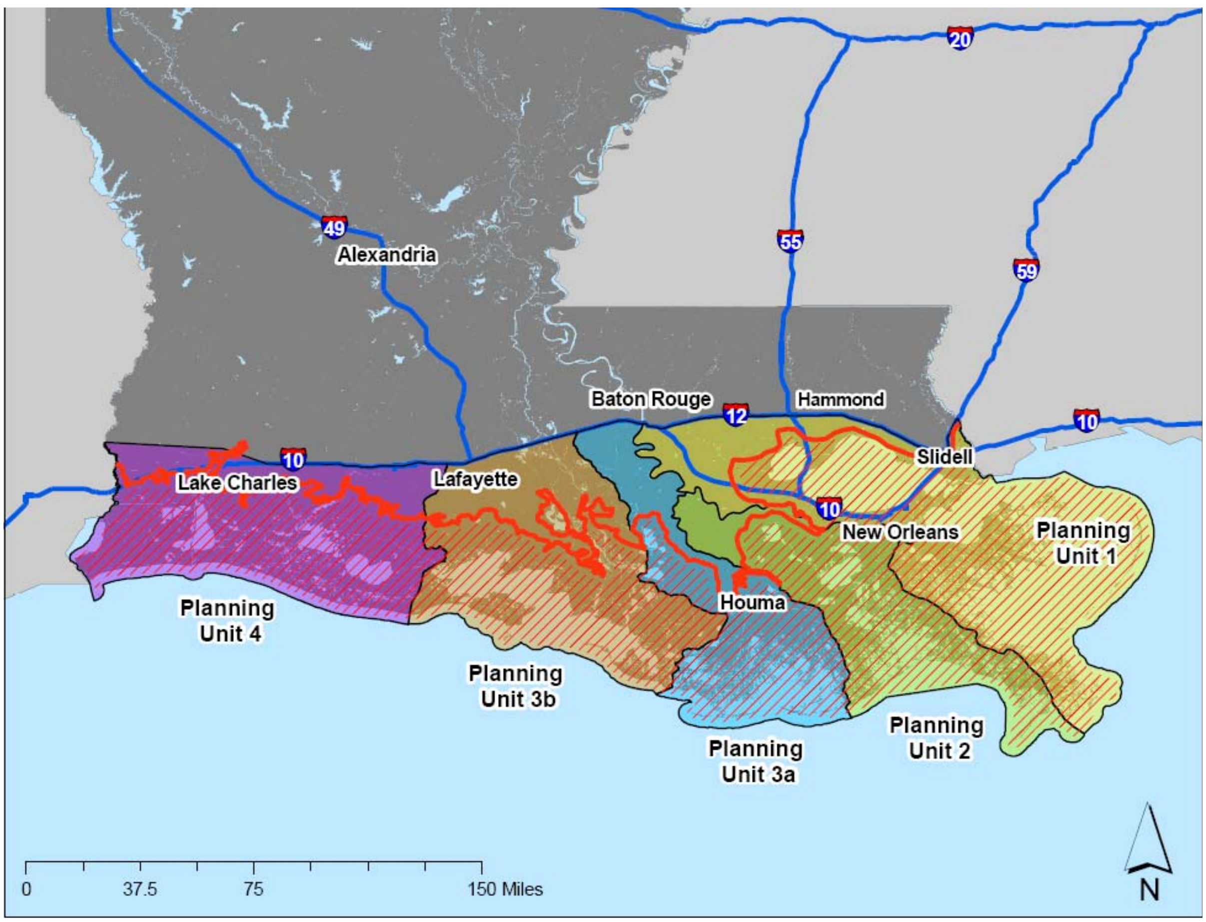
Existing Hurricane Threat

The following sections include the limits of hurricane surge inundation for the 1000-year event across the coast and the statistical water surfaces for the 100-year, 400-year, and 1000-year events in each of the planning units. More details on these conditions and how they were derived can be found in the *Hydraulics and Hydrology Appendix*.

Base Condition Surge Inundation Limits

Figure 4-3 illustrates the extent of the 1000-year hurricane surge inundation. The 100-year and 400-year limits are not shown on the map because they generally extend to the same limit but at lower levels.

Figure 4-3. LACPR planning area map showing the extent of the 1000-year hurricane surge inundation (in red).



Base Condition Water Surface Elevations

Figure 4-4 through **Figure 4-18** show statistical water level surfaces for the 100-, 400- and 1000-year return periods in each planning unit. Surfaces are made from outputs obtained from JPM-OS analysis of all grid points in the ADCIRC domain contained in the planning unit shown. The JPM-OS analysis uses the maximum stage computed at each of the grid points simulated in ADCIRC to compute the stage frequency at each of the grid points. Each of the planning units contains literally thousands of grid points which translate into thousands of stage frequencies from which statistical surfaces can be prepared.

To make the 100-year surface, the 100-year surge value is extracted from each of the frequency curves. Since the ADCIRC grid is geo-referenced, each 100-year stage can be plotted at its correct point in space; by connecting to the 100-year points a 100-year statistical surface can be made. The same procedure produces the 400-year and 1000-year surfaces. The 100-, 400- and 1000-year surfaces were chosen since those return intervals were used to design proposed protective works and levees for this effort.

The following legend appears on all maps and has been enlarged for better readability. Elevations are in feet NAVD 88 2004.65.

Figure 4-4. Statistical water surface for the 100-year event in Planning Unit 1.

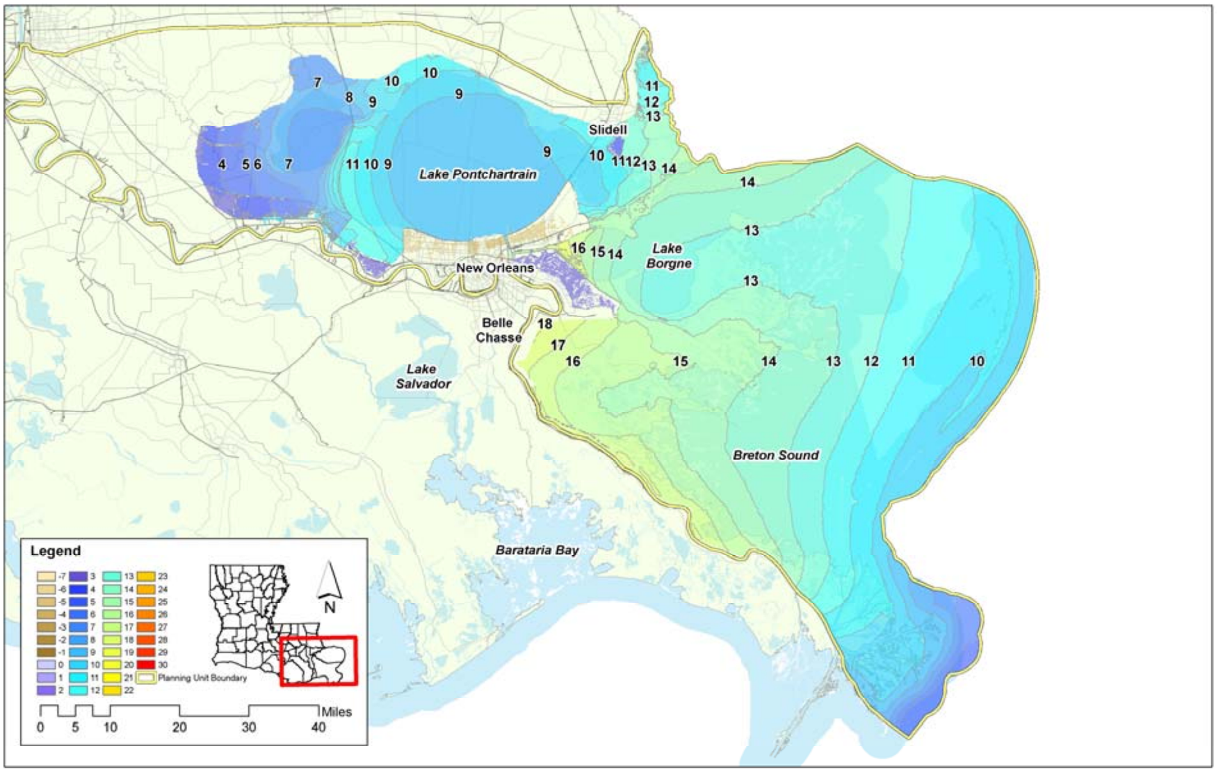


Figure 4-5. Statistical water surface for the 400-year event in Planning Unit 1.

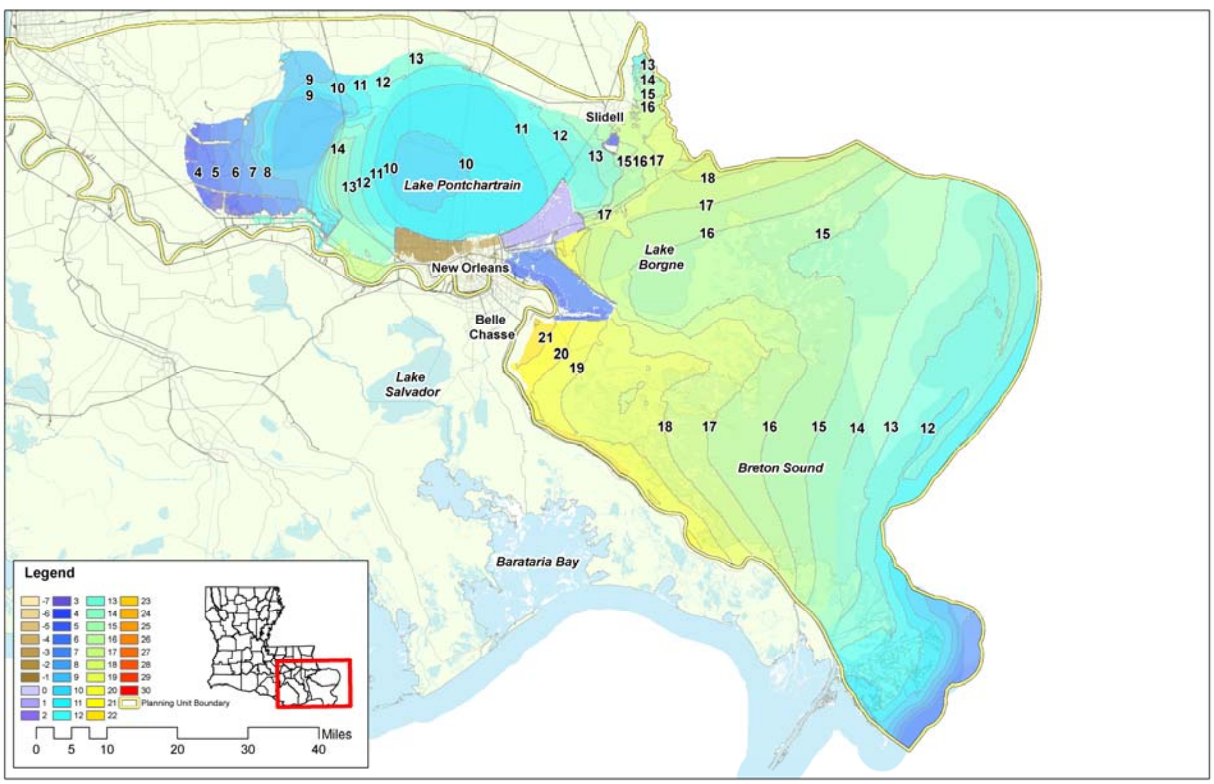


Figure 4-6. Statistical water surface for the 1000-year event in Planning Unit 1.

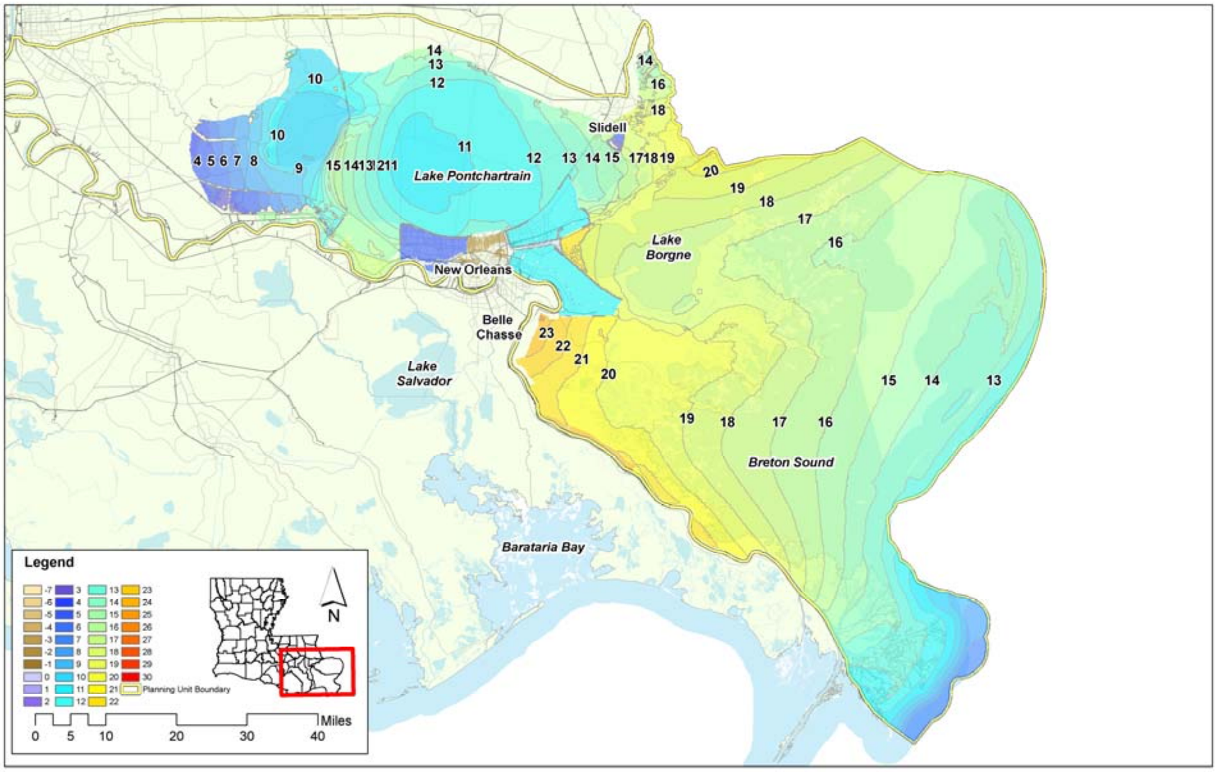


Figure 4-7. Statistical water surface for the 100-year event in Planning Unit 2.

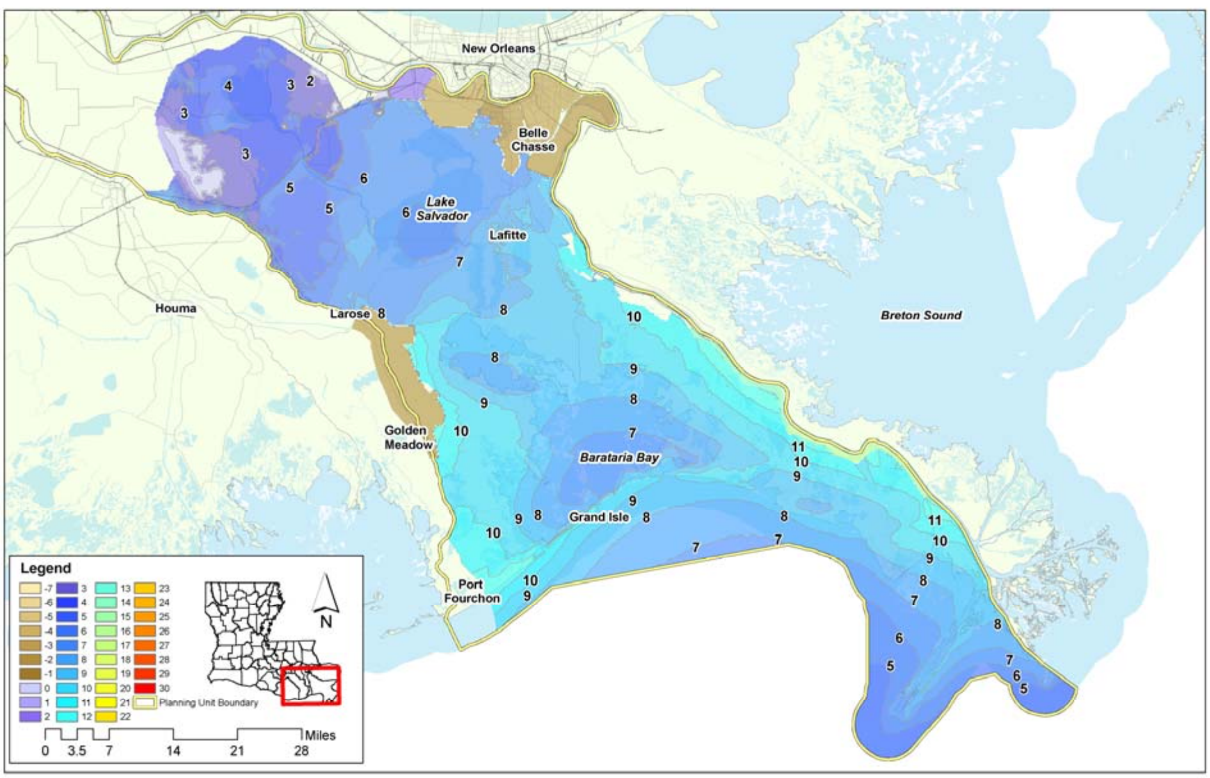


Figure 4-8. Statistical water surface for the 400-year event in Planning Unit 2.

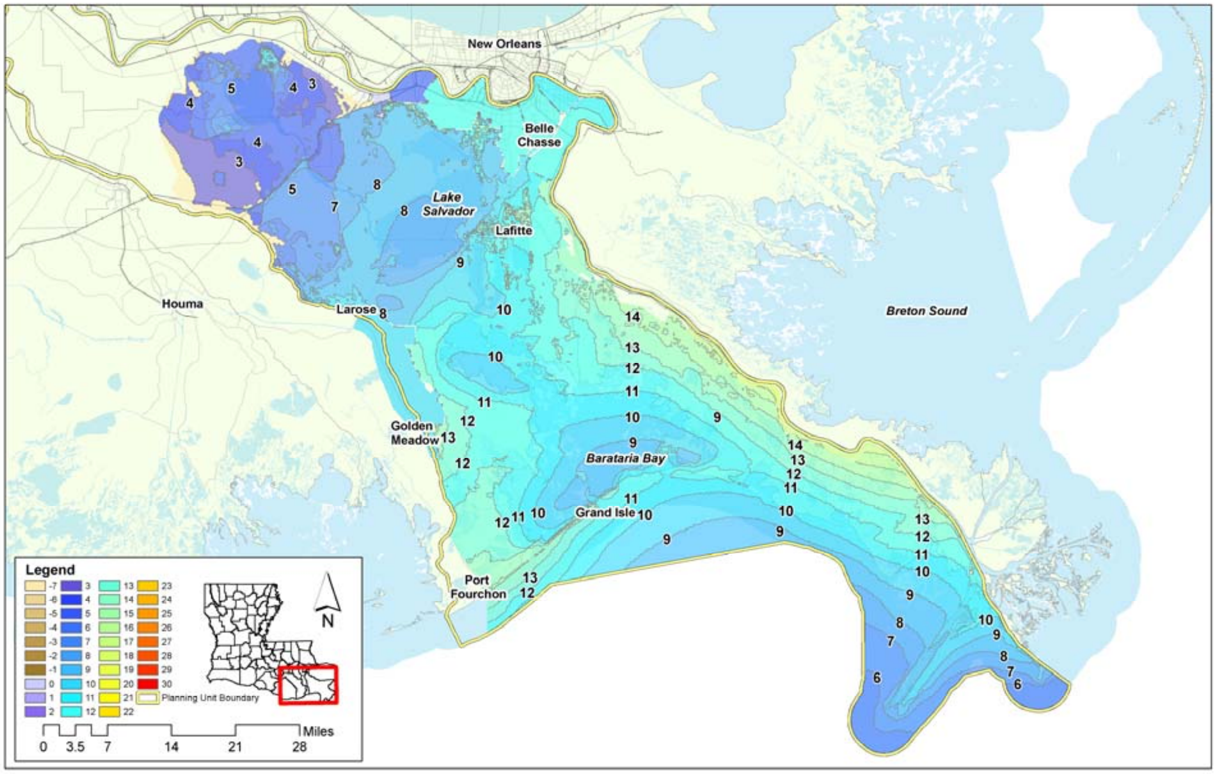


Figure 4-9. Statistical water surface for the 1000-year event in Planning Unit 2.

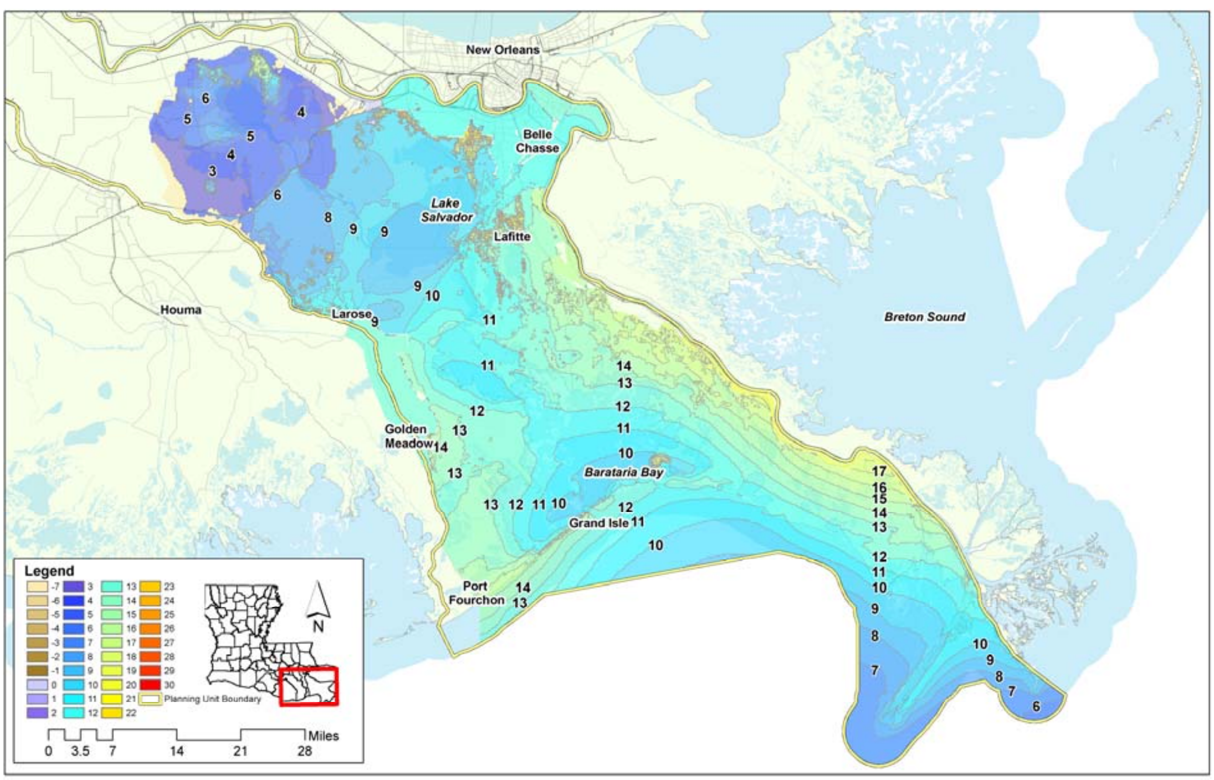


Figure 4-10. Statistical water surface for the 100-year event in Planning Unit 3a.

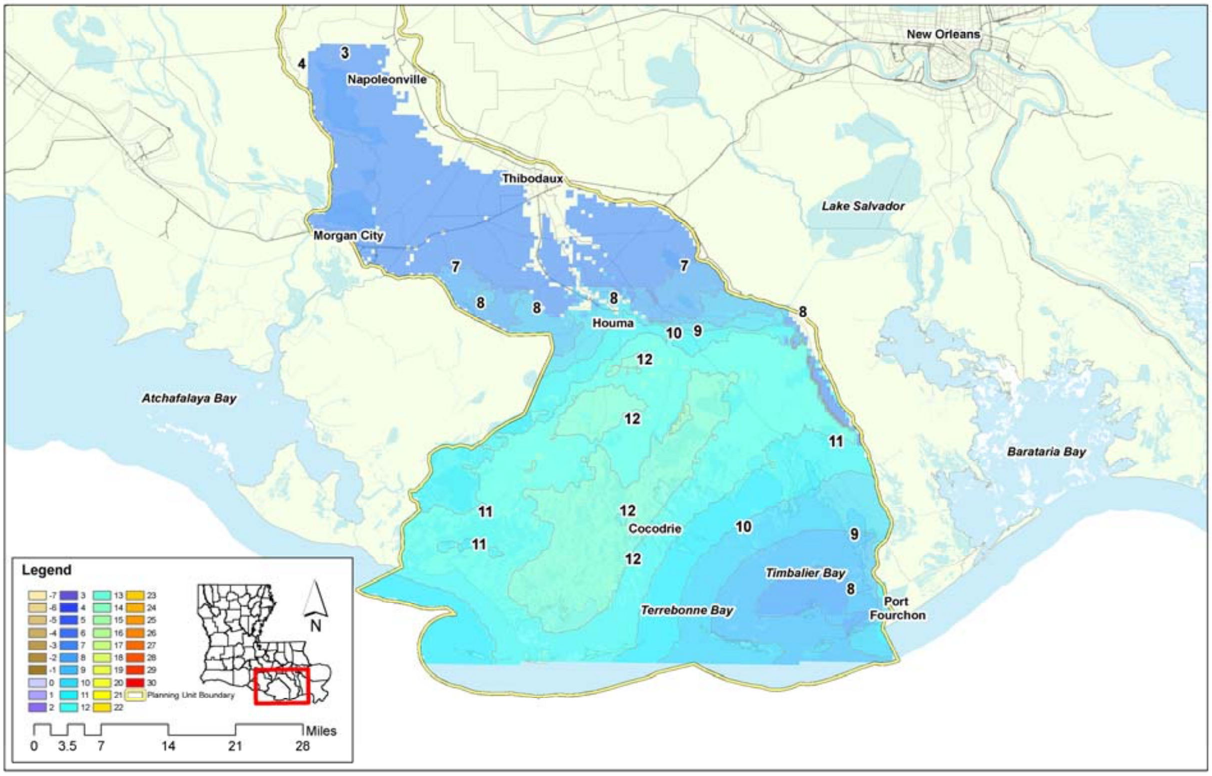


Figure 4-11. Statistical water surface for the 400-year event in Planning Unit 3a.

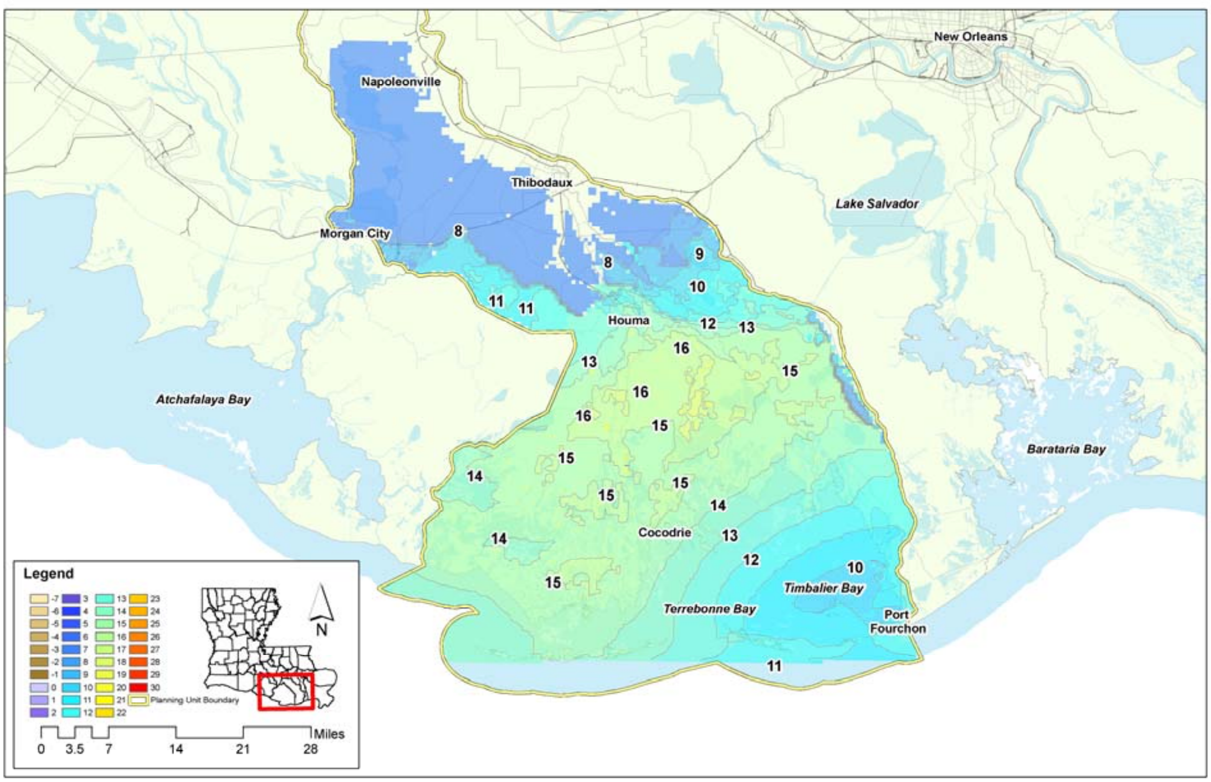


Figure 4-12. Statistical water surface for the 1000-year event in Planning Unit 3a.

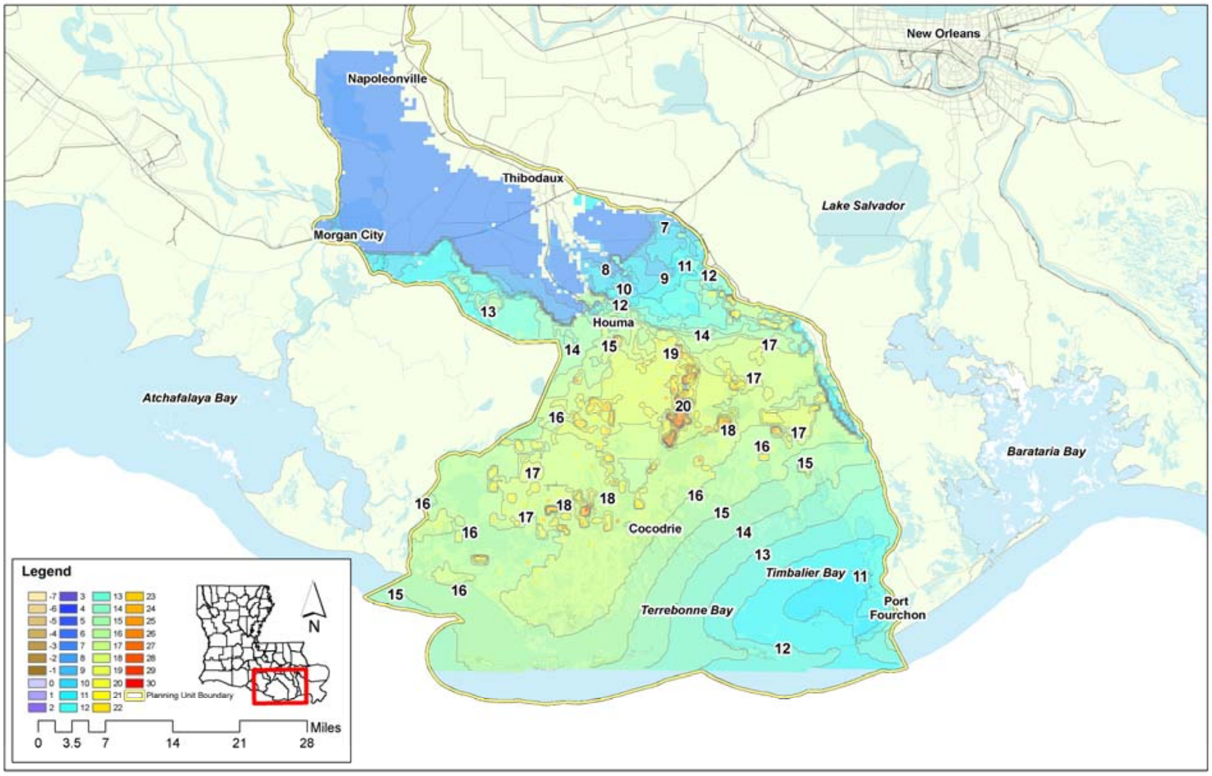


Figure 4-13. Statistical water surface for the 100-year event in Planning Unit 3b.

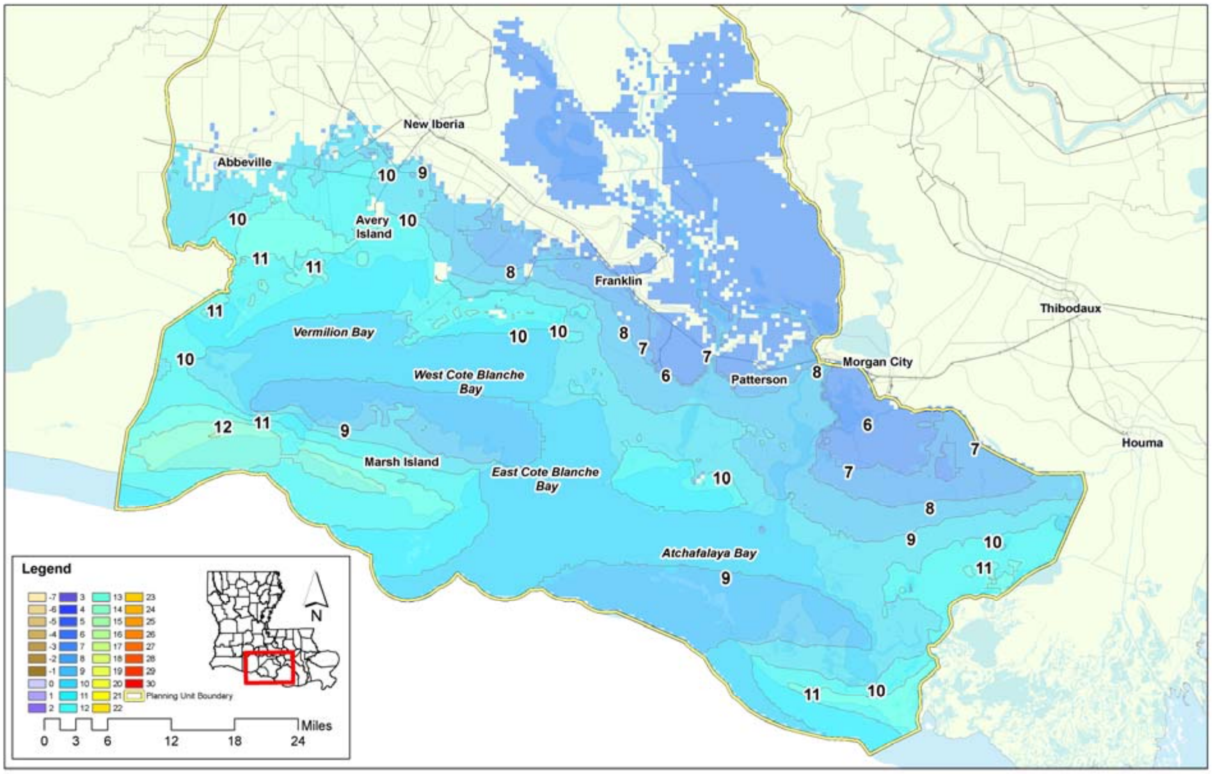


Figure 4-14. Statistical water surface for the 400-year event in Planning Unit 3b.

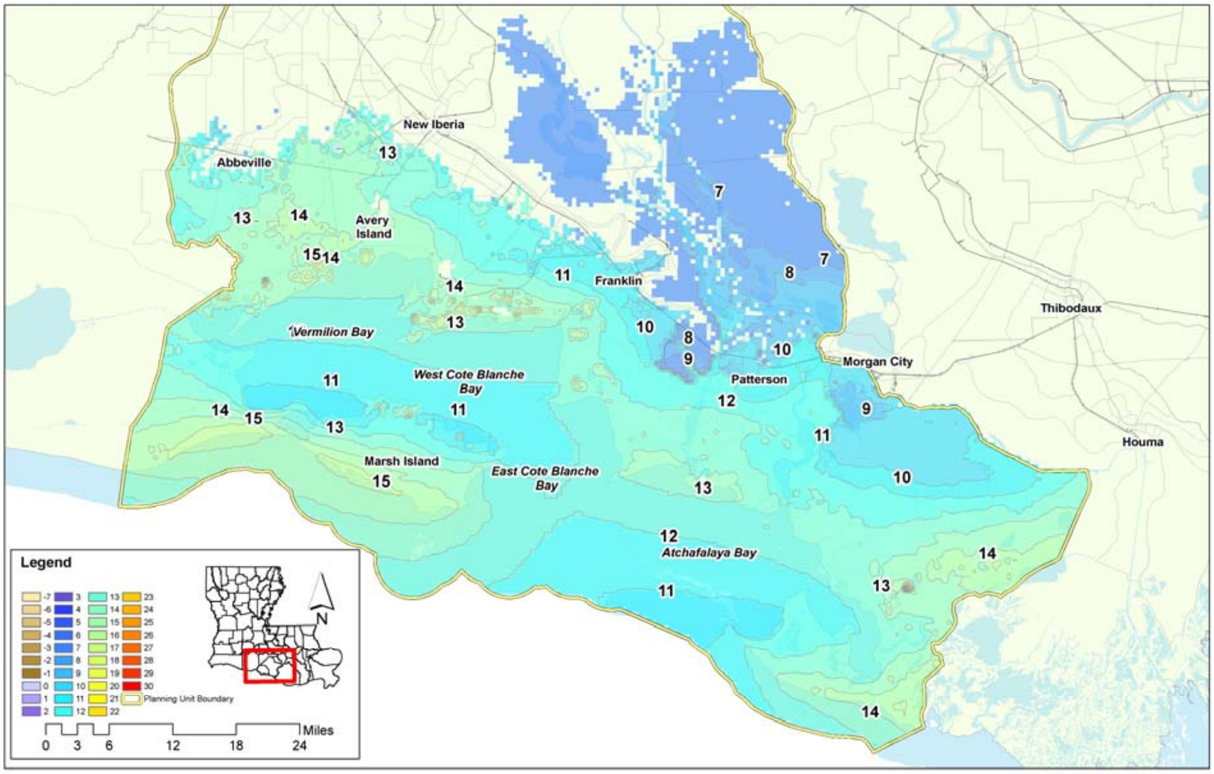


Figure 4-15. Statistical water surface for the 1000-year event in Planning Unit 3b.

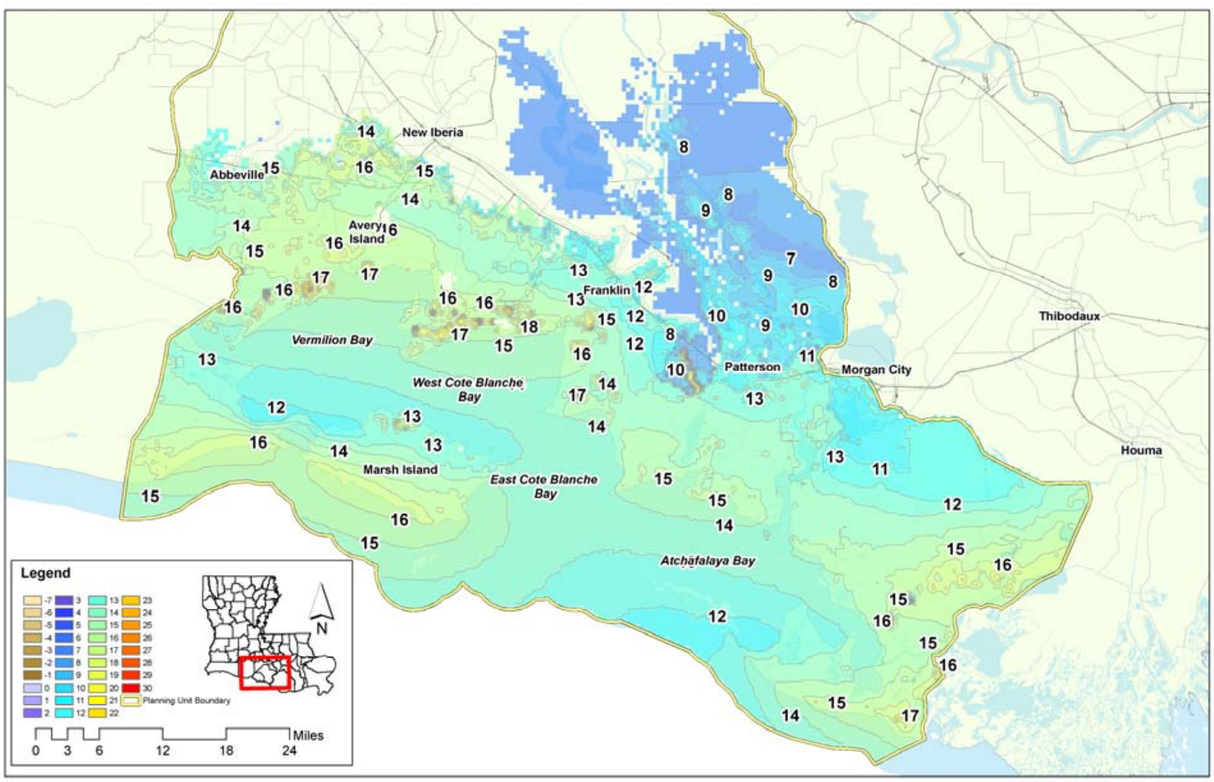


Figure 4-16. Statistical water surface for the 100-year event in Planning Unit 4.

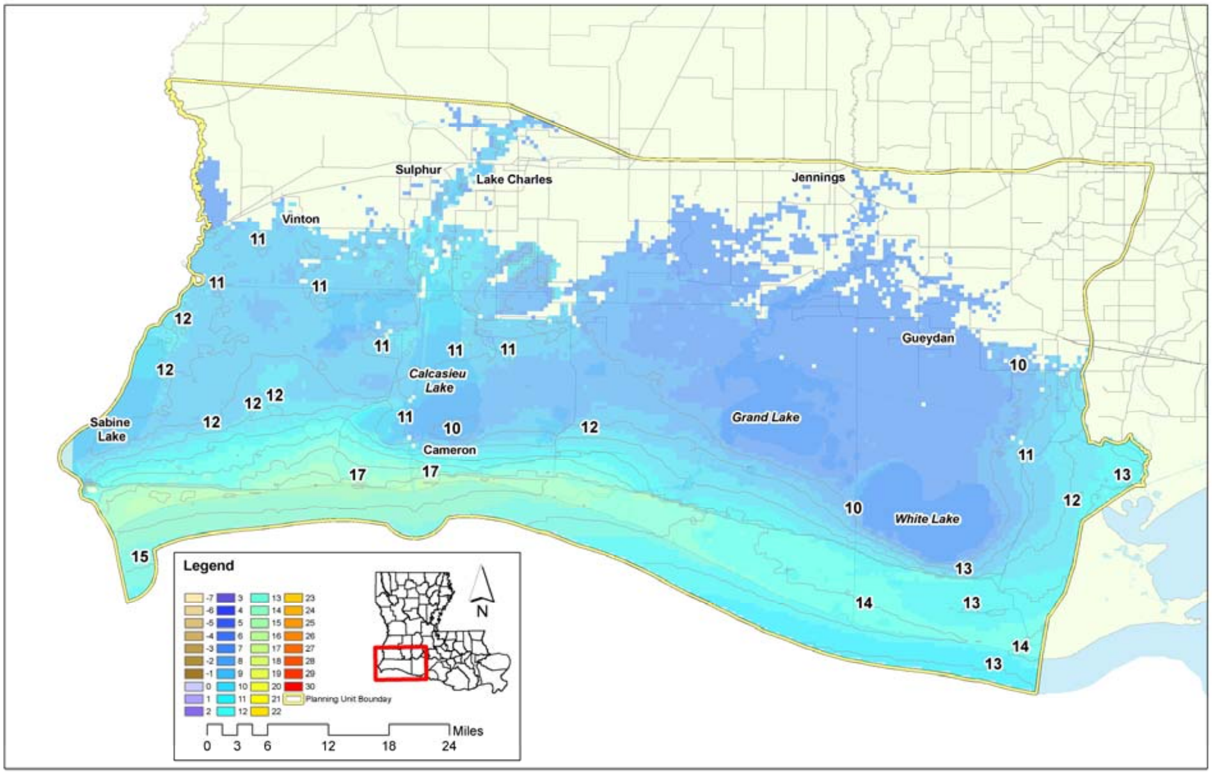


Figure 4-17. Statistical water surface for the 400-year event in Planning Unit 4.

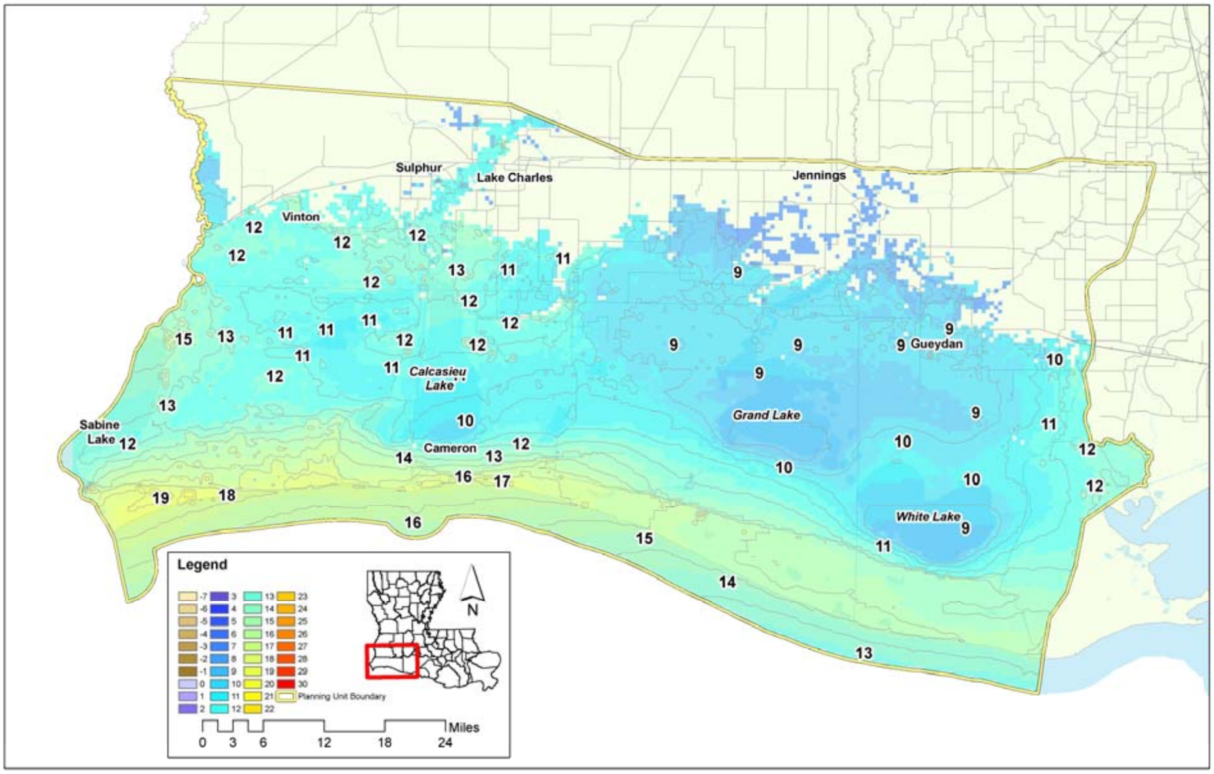
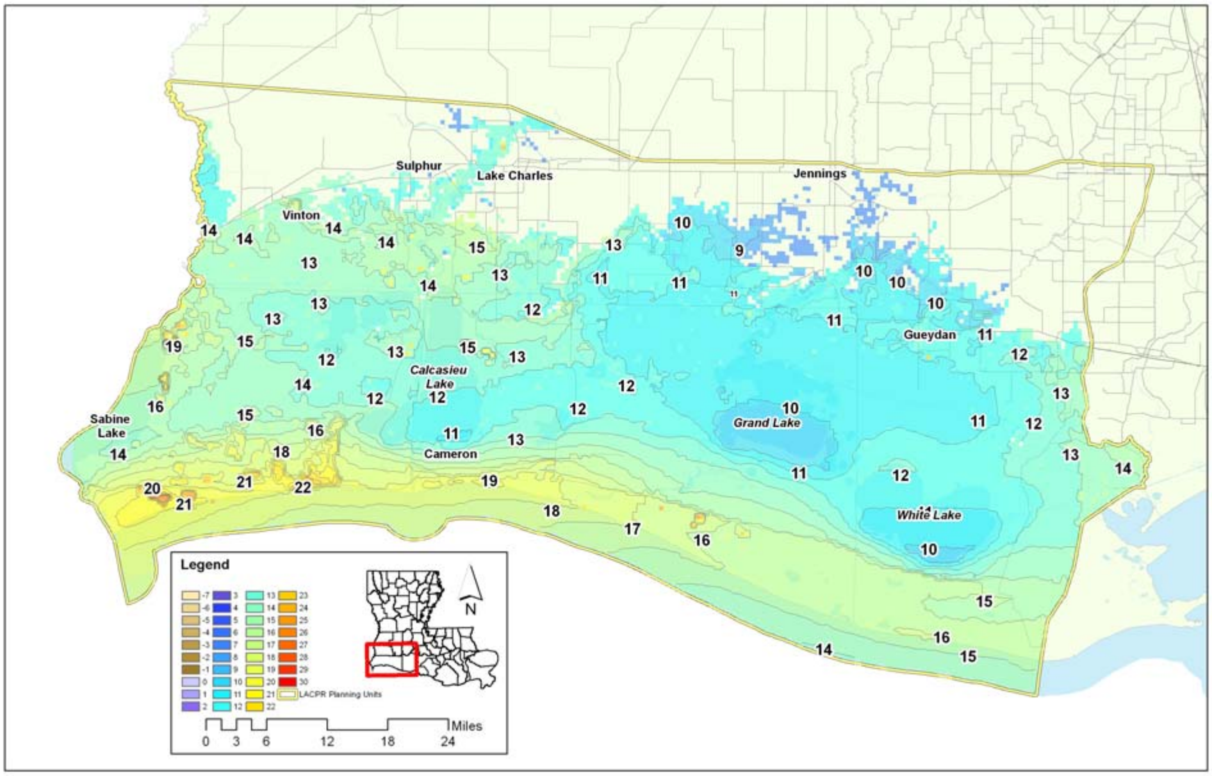


Figure 4-18. Statistical water surface for the 1000-year event in Planning Unit 4.



Future Conditions—Four Scenarios

Evaluating plans with respect to the without-project condition requires making predictions about conditions that will exist in the future. In order to make these "predictions," LACPR is using scenario planning, an approach not usually applied to USACE planning projects. The goal is to deal more effectively with uncertainty, especially where a quantitative assessment of uncertainty is not feasible or appropriate. Traditional USACE planning methods rely on a single forecast of the future condition.

Scenario planning is a purposeful examination of a complete range of potential futures. It is done to address the uncertainty inherent in long-term planning. Unlike forecasts, scenarios do not indicate what the future *will* look like so much as what the future *could* look like. Scenario construction stimulates creative ways of thinking that help planners, decision makers, and stakeholders break out of established patterns of assessing situations and plans so that they can better adapt to a rapidly changing and complex future. Consequently, scenarios are most appropriate under conditions where complexity and uncertainty are high.

The first and major thread of scenario planning is developing several without-project conditions rather than a single most likely future without a project. This method, developed for strategic planning by industry, recognizes large uncertainties in the future. Different realizations of the future could lead to quite different views about the best actions to take in the present. Uncertainties are addressed by describing different scenarios for each relevant future state of the world. Scenario planning acknowledges the critical influence of a few uncertainty drivers on the future condition that provides the base condition for evaluation.

For the analysis, the LACPR scenarios combine two levels of relative sea level rise with two levels of regional redevelopment (societal and economic recovery from Hurricanes Katrina and Rita) into four scenarios or alternative futures.

Relative Sea Level Rise Projections

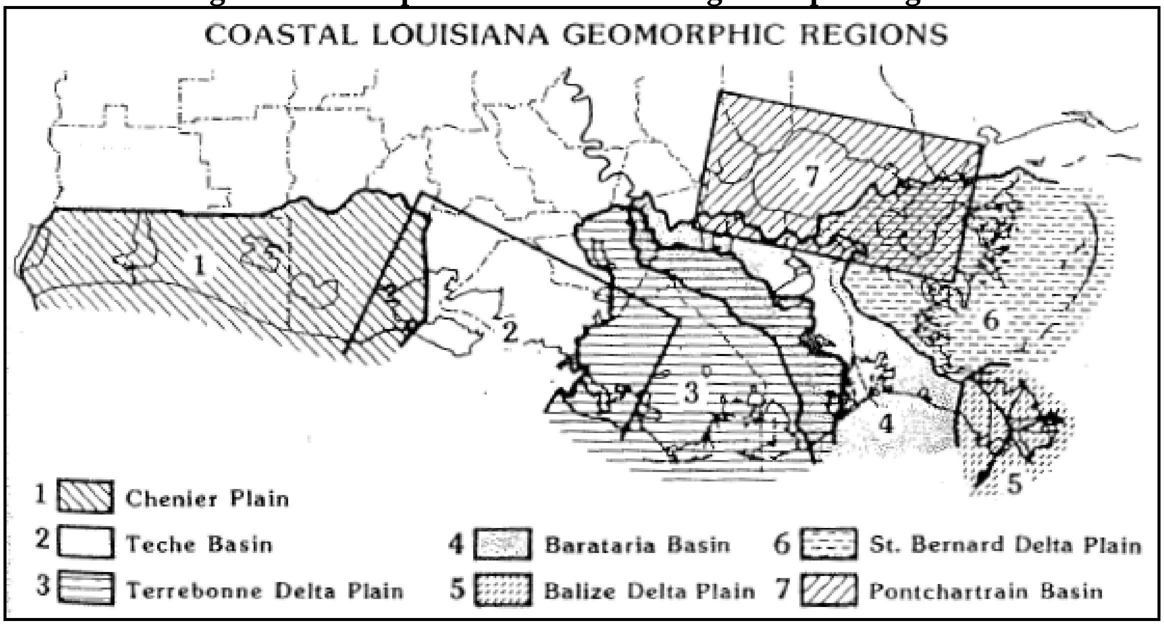
Future projections for rates of relative sea level rise are highly variable and contain a large amount of uncertainty. To accommodate this uncertainty, LACPR is considering two projections of future rates for relative sea level rise as described in the paragraphs below. For more detailed information on the development of these projections, see the *Hydraulics and Hydrology Appendix*.

Planning within coastal areas must consider the trends and variations between local mean sea level and land elevations. In areas where the local mean sea level is rising relative to land elevation, the relative sea level rise is often segmented into a global increase in water mass (eustatic rise), a rise in local water level due to density changes in the water (steric rise), and a drop in local land elevation (subsidence). Throughout the 20th century, the global average sea level rise due to eustatic and steric effects has been approximately 1.8 mm/year (Meehl, 2007). Tide gauges installed on geologically stable platforms in the northern Gulf of Mexico indicate a regional average sea level rise of approximately 1.8-2.0 mm/year during that same time period. Throughout coastal Louisiana the rates of subsidence exceed the rate of sea level rise by varying amounts, resulting in relative sea level rise rates significantly higher than the global and regional rates.

Though the causes of climate change and future projections of climate change are somewhat controversial, scientists have generally concluded that relative sea level has been rising across coastal Louisiana and may continue to do so in the future. Since quantifying the rates of sea level rise that may occur in different areas of Louisiana is so difficult, the LACPR scenario analysis includes two different relative sea level rise projections to demonstrate how different project designs would respond to a range of sea level rise rates. Projection 1 estimates are based on Intergovernmental Panel of Climate Change (IPCC) estimates (Meehl, 2007) and Projection 2 estimates (which are higher than Projection 1 estimates) are based on National Research Council (NRC) estimates (NRC, 1987).

Both the National Ocean Service and the USACE have maintained long-term water-level gauges that can be used to calculate historic relative sea level rise rates across coastal Louisiana. Because of the distance between these gauges, and the engineering difficulty associated with using numerous historic relative sea level rise rates for analysis, coastal Louisiana was divided into different geomorphic regions for relative sea level rise analysis. Within each geomorphic region, subsidence rates were thought to be relatively uniform due to relatively homogeneous geologic conditions. The geomorphic regions considered were based on the historic shifting of the Mississippi River's main stem and the associated delta lobes the river created. Based on similarities in historic relative sea level rise rates, alternative screening further grouped the regions into three primary geomorphic regions (see **Figure 4-19** below): the Chenier Plain (region 1), the Delta Plain (regions 2-6), and the Pontchartrain Basin (region 7).

Figure 4-19. Map of coastal Louisiana geomorphic regions.



Source: Penland, 1990.

Both the 1987 NRC global mean sea level rise projections and the 2007 IPCC global mean sea level rise projections, combined with estimates for local and regional subsidence rates across coastal Louisiana determined the future rates of relative sea level rise. While the 2007 IPCC projections are considered the most current and rigorous effort to estimate future global mean sea level rise rates, some criticism has been voiced that these projections do not adequately consider the potential for extreme scenarios, such as massive ice loss and melting in Antarctica. The 2007 IPCC mean central value estimate for global mean sea level rise by 2100 is 0.343 meters (1.1 feet) and the upper limit value is 0.59 meters (1.9 feet). Due to the uncertainties associated with the IPCC estimate methods, a conservative value of 0.5 meters (1.6 feet) of rise by 2100 is used for rigorous sensitivity analysis.

To account for possible extreme scenarios of global mean sea level rise and the associated relative sea level rise across Louisiana, the sensitivity analysis also considered the “Curve III” value from the 1987 NRC report, which estimates a global mean sea level rise of 1.5 meters (4.9 feet) by 2100.

Estimates of local and regional subsidence rates were calculated by subtracting the regional historic sea level rise rate (2.0 mm/year) from the local and regional relative sea level rise rates described earlier. These subsidence rates were combined with the future projections described in the previous two paragraphs to determine local and regional projections for future rates of relative sea level rise. **Table 4-2** summarizes the relative sea level rise values developed for the scenarios.

Table 4-2. Relative sea level rise values over a 50-year period of analysis.

	Relative Sea Level Rise Values between 2010 and 2060 in meters (in feet)		
Basis for Value	**Pontchartrain Basin (Planning Unit 1)**	**Delta Plain (Planning Units 2, 3a, and 3b)**	**Chenier Plain (Planning Unit 4)**
Historic rate (for comparison only)	0.2 m (0.7 ft)	0.4 m (1.3 ft)	0.2 m (0.7 ft)
Future Projection 1 (based on Intergovernmental Panel of Climate Change values)	0.4 m (1.3 ft)	0.6 m (1.9 ft)	0.4 m (1.3 ft)
Future Protection 2 (based on National Research Council values)	0.8 m (2.6 ft)	1.0 m (3.2 ft)	0.8 m (2.6 ft)

Redevelopment Projections

The building stock and the location of the economic assets vulnerable to flooding will depend on two factors: (1) redevelopment rates and (2) redevelopment patterns. Projections of future development and land use allocation were provided by Calthorpe Associates, an urban planning agency contracted by the State of Louisiana as part of the Louisiana Speaks forum. More details on the redevelopment projections used for the LACPR analysis can be found in the *Economics Appendix*.

For the LACPR analysis, two future redevelopment rates, high employment and business-as-usual, were used to project the amount of assets that could be damaged. Both of these rates assume continued growth rather than population decline. The business-as-usual rate reflects continued employment opportunities in industries traditionally found in South Louisiana, while the high employment rate assumes employment growth in industrial sectors new to South Louisiana.

In addition, two land use allocation patterns, dispersed and compact, were used to spatially locate the development in the planning area. These two patterns represent the two extremes for land use allocation. Dispersed land use means development is spread over a greater land area and is typically composed of single-family homes. Compact means development is concentrated, for example a town center with multi-story buildings.

These redevelopment rates and redevelopment patterns were combined as follows for the future scenario analysis:

- ***High employment, Dispersed Population* –** Based on the high employment redevelopment rate and used in future scenarios 1 and 2.
- ***Business-as-usual, Compact Population*** - Based on the business as usual redevelopment rate and used in future scenarios 3 and 4.

These two redevelopment types were chosen as representative of several ways in which redevelopment could occur. The difference in damages for each of these projections can be used to measure the uncertainty in damages due to redevelopment. For this sensitivity analysis, the high employment, dispersed population projection would result in the most damages and the business-as-usual, compact population projection would result in the least damages.

Four Scenarios Based on Relative Sea Level Rise and Redevelopment

Table 4-3 presents the four LACPR scenarios, which capture a wide range of possible futures.

Table 4-3. The four LACPR future scenarios.

		Redevelopment	
		High Employment, Dispersed Population	**Business-as-usual, Compact Population**
Relative Sea Level Rise	**Projection 1**	Scenario 1	Scenario 3
	Projection 2	Scenario 2	Scenario 4

Each alternative plan was evaluated for each of four future scenarios. The performance of each alternative plan was evaluated on the basis of metrics derived from hydromodeling data and other analyses.

Assets Inventory

A GIS-based methodology similar to that used by the IPET was used to assess flood damages to residential and non-residential structures, their contents, and vehicles in the planning area. More details on the assets inventory used for the LACPR analysis can be found in the *Economics Appendix*.

Inputs to the GIS framework for South Louisiana included each of the following:

1) **Residential Structures** - Depreciated exposure values of residential structures obtained from the general building stock portion of the Hazard U.S.-Multihazard (HAZUS-MH), a multi-hazard loss estimation tool developed by the Federal Emergency Management Agency (FEMA) and the National Institute of Building Sciences (NIBS);
2) **Non-Residential Structures** - Depreciated exposure values of non-residential structures, including public infrastructure and businesses, obtained from the Louisiana Department of Labor (LDOL) and the Louisiana State University;
3) **Contents of Structures** - Residential and non-residential contents values;
4) **Vehicles** - Depreciated exposure values of vehicles associated with residential and non-residential structures are based on the Manheim Used Vehicle Value Index and data obtained from the Louisiana Department of Motor Vehicles.
5) **Damages Related to Depth of Flooding** - Depth-damage relationships developed by panels of building and construction experts as part of previous USACE feasibility studies; and
6) **Topography -** Elevation data were obtained through satellite technology and computer modeling;

Stage-Damage Relationships

The GIS database of assets as described was used within a geospatial environment to generate a water elevation or stage-damage relationship for each census block. Flood damages were calculated at one-foot increments from the beginning-damage elevation to an elevation where damages for all the structural categories have reached a maximum. Six general damage categories were considered:

1) Single-family residential;
2) Multi-family residential;
3) Manufactured housing/mobile homes;
4) Commercial, industrial, public;
5) Agricultural; and
6) Vehicles.

The damages reflect October 2006 price levels, but are modified to reflect post-Katrina and Rita population shifts and expected recovery projections. Projections of future development and land use allocation were provided by Calthorpe Associates, an urban planning agency contracted by the state of Louisiana as part of the Louisiana Speaks forum. It should be noted that any residential and non-residential properties and their vehicles that incurred flood damages from Hurricanes Katrina and Rita would not be included in this analysis until the owners of these properties had reoccupied their structures.

Emergency Costs

A flooded community typically incurs a variety of flood-related costs not associated with structural damages. The emergency costs associated with inundated residential properties include evacuation and subsistence, clean up and reoccupation costs, debris removal, and landscaping costs throughout the necessary duration for recovery. The emergency costs associated with inundated non-residential properties include clean up and restoration costs, recovery of business records, and landscaping. These costs are incurred either by the Federal, State, and local government, the occupants of inundated residential properties, or the owners of inundated non-residential properties. An emergency cost depth-damage relationship for residential and non-residential properties was developed for each increment of flooding up to 15 feet above the first floor elevation. These depth-damage relationships were then combined in the GIS framework with the number of residential and non-residential structures inundated at each one-foot increment of flooding to develop a stage-damage relationship for the total of all residential and non-residential emergency cost categories.

Transportation

The GIS framework was used to determine the number of miles of highways, streets, and railroad tracks that would be inundated by the stages associated with each one-foot increment of flooding. Data obtained by USACE New Orleans District staff were used to revise the depth-damage relationships for highways, streets, and railroad tracks that had been developed as part of a Mississippi River and Tributaries study entitled Economic Data Survey New Orleans District, which was conducted for the Lower Mississippi Valley Division in September 1980.

These depth-damage relationships were then combined in the GIS framework with the number of residential and non-residential structures inundated at each one-foot increment of flooding to develop a stage-damage relationship for the total of all highways, streets, and railroad tracks.

Agricultural Resources

In addition to the stage-damage relationships developed for residential and non-residential structural damages and for the other emergency cost categories, stage-damage relationships were developed for the agricultural resources in the planning area. The National Agricultural Statistics Service GIS database for the year 2005 (pre-Katrina and Rita) was used to provide the location of each of the various crops farmed in the LACPR planning area. These crops include corn, cotton, rice, sorghum, soybeans, winter wheat, small grains (alfalfa, oats, millet, and rye) and hay, sugar cane, fallow cropland, pecans, and pasture. The number of citrus acres in Plaquemines Parish was provided by the Louisiana State University Agricultural Center (LSU AgCenter) and their location was estimated based on the location of fallow cropland in the area. The LSU AgCenter provided the number of acres of crawfish farming for each parish, and it was assumed that these acres were located in the same area as the rice acres.

The total damage rate developed for each crop, including both crop loss and non-crop loss, was multiplied by the number of cleared acres inundated in order to calculate the total loss from inundation for each crop. The reduction in the acres inundated under the with-project alternatives was compared to the without-project condition and multiplied by the damage rates in order to determine the damages and benefits associated with each alternative.

Expected Damages for Base Condition and Future Scenarios

Table 4-4 presents a range of without-project expected damages for the 10-year, 100-year, 400-year, 1000-year, and 2000-year event for each planning unit. The damage numbers are based on each event happening at the same time across the entire planning unit and are therefore not representative of an actual event.

Table 4-4. Range of without-project damages for the base condition and into the future.

Planning Unit	Alternative	10-Year Damage ($billions)	100-Year Damage ($billions)	400-Year Damage ($billions)	1000-Year Damage ($billions)	2000-Year Damage ($billions)
1	Base Condition	5.0 to 5.4	9.4 to 9.7	35.3 to 36.1	46.2 to 47.6	65.6 to 67.0
	Future Scenarios	6.4 to 8.1	16.2 to 29.4	62.9 to 107.1	75.9 to 111.1	76.9 to 112.5
2	Base Condition	2.6 to 4.4	4.6 to 6.4	29.9 to 33.9	31.7 to 35.9	32.2 to 36.5
	Future Scenarios	3.6 to 6.4	30.1 to 33.8	35.1 to 45.7	36.1 to 47.3	36.5 to 48
3a	Base Condition	8.7 to 10.3	10.3 to 12.1	13.8 to 15.3	15.4 to 16.8	16.0 to 17.5
	Future Scenarios	12.8 to 17.1	14.7 to 18.1	17.9 to 22.8	19.0 to 24.4	19.5 to 25.1
3b	Base Condition	2.7 to 2.9	3.4 to 3.7	5.5 to 6.1	7.1 to 7.8	8.0 to 8.6
	Future Scenarios	4.2 to 5.6	5.2 to 6.5	8.1 to 9.6	10.0 to 10.8	10.6 to 11.1
4	Base Condition	2.5 to 2.7	3.3 to 3.4	4.9 to 5.4	6.6 to 7.6	7.4 to 8.5
	Future Scenarios	3.3 to 4.7	4.3 to 5.7	7.6 to 9.9	9.3 to 11.9	10.2 to 13.1

All values in based on 2006 price levels and water surface elevations at the 90% confidence level.

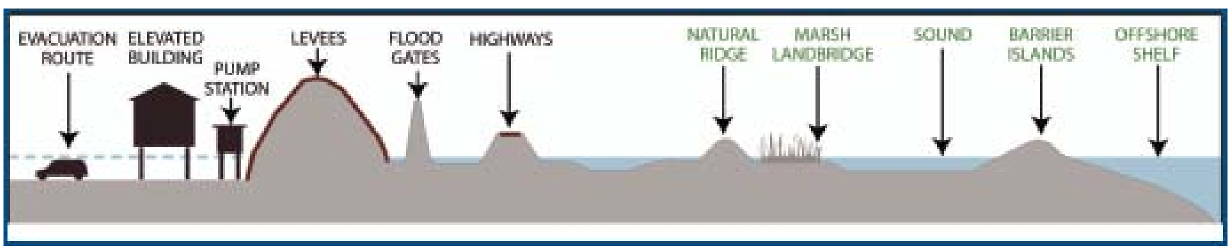
Section 5. Development of Alternative Plans

As mentioned earlier, the objectives of the LACPR effort are to reduce overall risk to people, economic assets, coastal resources, and cultural resources along the Louisiana coast from storm events. Generally, this report describes risk as exposure of vulnerable people or assets, multiplied by the probability of threat occurrence, resulting in undesirable consequences to people and assets at risk. Storm risk reduction measures can be formulated in two ways, either by reducing the probability of adverse consequences from the occurrence or by reducing exposure to the occurrence, thereby reducing the consequences themselves. No alternatives have been formulated that will provide total protection to the entire planning area against all potential storms. The reason is a matter of practicality, technical inability and construction challenges, and extremely high costs. Evaluation of damages did include a 2000-year event in the frequency curve, but comparable design was not developed.

Multiple Lines of Defense Strategy

One of the assumptions used to develop the State Master Plan and adopted by LACPR is that hurricane risk reduction plans must rely on multiple lines of defense. The multiple lines of defense strategy involves using natural features such as barrier islands, marshes, and ridges to complement engineered structures such as highways, levees, and raised homes (see **Figure 5-1**).

Figure 5-1. Depiction of multiple lines of defense strategy.



Source: Lake Pontchartrain Basin Foundation

Another extension of the multiple lines of defense approach, which has been considered in the LACPR plan formulation and analysis, is the use of overtopping levees, or weirs, that would move the primary structural line of defense away from populated areas and allow storage of storm surge behind them, reducing the required height of levees closest to populated areas. The multiple lines of defense approach avoids reliance on single risk reduction measures, which, if compromised, would leave vulnerable areas without recourse. Residents of coastal Louisiana have used a multiple lines of defense strategy for hundreds of years, building homes and settlements on high ground protected by natural ridges, barrier islands, and more recently, levees.

Within the context of a multiple lines of defense or comprehensive system, numerous risk reduction measures can be combined to form alternative plans. Each type of measure provides unique opportunities to reduce risk of hurricane-induced flooding. Combining these different types of measures provides opportunities to develop comprehensive solutions to the flooding and habitat loss problems of the Louisiana coast. These combined approaches produce a multiple lines of defense system against storm surge.

For the LACPR effort,

- **Coastal restoration alternatives**, consisting of hundreds of **coastal restoration measures**, are the foundation of every alternative, except the no action alternative. Examples of coastal restoration measures include land/marsh-building river diversions, freshwater redistribution, mechanical marsh creation, barrier island/shoreline restoration, bank/shoreline stabilization, and ridge restoration.
- **Structural measures and alternatives** reduce flood risk using features that are designed to withstand the forces of storm events, such as surge-reduction weirs, floodgates, continuous earthen levees, floodwalls, and ring levees.
- **Nonstructural measures and alternatives** reduce the exposure to risk by removing vulnerable populations and assets from the threat through measures such as buyout of properties or raising structures in place. Additional nonstructural measures include wet and dry flood-proofing of critical facilities.
- **Comprehensive alternatives** (not to be confused with the comprehensive plan for the coast) refer to plans that contain all three types of risk reduction measures—nonstructural, structural, and coastal restoration—presenting a multiple lines of defense strategy, providing comparable levels of risk reduction to all economic assets in the surge impacted areas.

Two of LACPR's many stakeholder groups, the Coalition to Restore Coastal Louisiana and the Lake Pontchartrain Basin Foundation, have presented a report titled *Comprehensive Recommendations Supporting the Use of the Multiple Lines of Defense Strategy to Sustain Coastal Louisiana*. The LACPR effort has incorporated some of the ideas from these stakeholder groups as well as many others. More information on public and stakeholder interaction throughout the LACPR process can be found in the *Stakeholder Appendix*.

Inventorying Measures in the Plan Formulation Atlas

Once problems and opportunities were identified, the first phase in the plan formulation process was to identify risk reduction measures, which are features or activities that can be implemented to address one or more planning objectives. This inventory was collected through extensive public involvement in partnership with the development of the State Master Plan to identify hurricane risk reduction strategies for South Louisiana. Through this partnership, the State developed the State Master Plan to provide a long-term vision for hurricane risk reduction and coastal restoration.

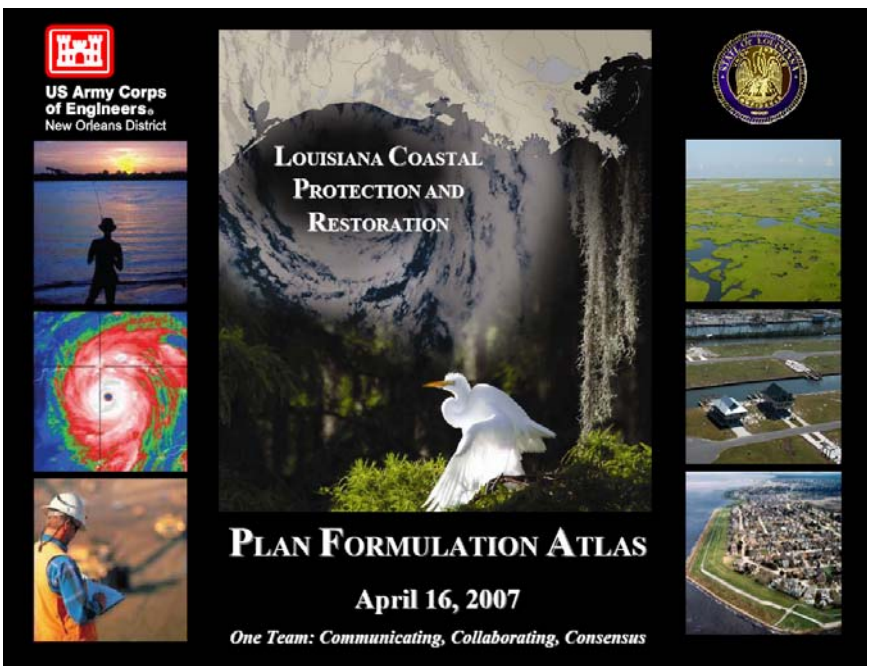
Numerous risk reduction measures were identified during the development of the State Master Plan. In addition, the team gathered measures from several sources, including other coastal area plans and programs; local, parish, and landowner plans; planning workshops; the National Environmental Policy Act (NEPA) scoping process; and other public input. Broad, multi-disciplinary organizational team representatives from coastal parishes, levee districts, State and Federal agencies, non-governmental agencies, and academia, as well as concerned citizens, provided guidance and ideas for identifying measures. Many groups and individuals had already been working together on Federal wetland restoration initiatives including the Coastal Wetlands Planning, Protection and Restoration Act (CWPPRA) Program and the Louisiana Coastal Area

(LCA) Study. These relationships facilitated gathering interested parties at many public meetings and workshops held across coastal Louisiana. The State of Louisiana employed a similar information gathering process during the formulation of the State Master Plan.

The LACPR Plan Formulation Atlas (dated April 16, 2007) documents this extensive collaborative effort by providing an inventory of the hundreds of coastal protection and restoration measures identified for further consideration in developing a comprehensive risk reduction plan for South Louisiana. The Atlas was also used to engage stakeholders in the LACPR effort. The complete LACPR Plan Formulation Atlas is available online at *www.lacpr.usace.army.mil*.

The LACPR Plan Formulation Atlas as an Initial Screening Tool

The possible combinations of structural, nonstructural, and coastal restoration measures for South Louisiana is unmanageable because of the complexity of the planning area. In order to combine the measures into a reasonable set of alternatives, these options needed to be screened. The Plan Formulation Atlas functioned as a reference manual to initiate this screening as well as to continue stakeholder involvement. Since April 2007, the team has continued to refine the measures and alternatives presented in the Plan Formulation Atlas to develop the array of alternatives for evaluation and comparison.



Cover of the LACPR Plan Formulation Atlas

Additional Considerations

Though extensive, the LACPR effort by no means reflects the entire set of ideas to be considered for risk reduction in South Louisiana. In addition to the measures proposed in the Plan Formulation Atlas, many independent groups have produced information, letters, reports, and articles related to the recovery, restoration, and protection of coastal Louisiana after the 2005 hurricanes. The following organizations have contributed plans or ideas to the LACPR and the State Master Plan teams:

- Bring New Orleans Back Committee
- Flood Protection Alliance
- Interagency Performance Evaluation Task Force
- Federal Emergency Management Agency
- American Society of Civil Engineers
- Lake Pontchartrain Basin Foundation
- Coalition to Restore Coastal Louisiana
- Barataria-Terrebonne National Estuary Program
- Biloxi Marshlands Corporation
- Independent scientists and engineers both nationally and internationally

Much can be answered regarding the plans and ideas provided from these groups through analysis of the alternatives for LACPR. Continued collaboration will lead to better and more defined plans in the future.

Coastal Restoration Measures and Alternatives

Coastal features are the first line of defense against hurricane surge and waves. Therefore, sustaining the integrity of the estuarine environments in coastal Louisiana, including the various landscape features that make up those environments, is critical to ecological health as well as surge and wave reduction, and by extension, the social and economic welfare of the region.

Preliminary model analyses of storm surge levels and wave magnitudes demonstrate the potential value of coastal features to lowering storm damage risks. The role of coastal features in reducing hurricane storm-surge effects depends on a variety of factors, including the physical characteristics of the storm, coastal geomorphic setting, and the track of a storm when it makes landfall. While the models show benefits from additional marsh, island, and landbridge habitat in some areas, the effects of allowing existing features to degrade in these areas are even more pronounced. Thus, sustaining the integrity of the estuarine environments in coastal Louisiana is a key component of a comprehensive storm risk reduction strategy for the region.

Habitat Evaluation Team

As part of the overall LACPR team, a Habitat Evaluation Team, consisting of USACE, State of Louisiana, and various Federal resource agency members, developed a suite of coastal restoration alternatives. The Habitat Evaluation Team evaluated multiple restoration alternatives in addition to the future without-project condition to achieve coastal restoration goals. More details on the formulation and evaluation of coastal restoration alternatives can be found in the *Coastal Restoration Plan Component Appendix.*

In developing alternatives, measures that would significantly contribute to wetland maintenance processes at a basin scale were considered to be of greatest importance. Given the effects of relative sea level rise, sediment inputs and restoration of natural wetland maintenance processes were considered to be essential for achieving the highest degree of ecosystem sustainability possible. Restoration of natural deltaic processes through diversions of Mississippi River freshwater nutrients and sediment were considered essential for the restoration of self-sustaining coastal wetlands. Marsh creation measures strategically located to provide basin or subunit-level benefits were also considered. Similarly, natural landscape features such as ridges and barrier islands were considered, provided those landscape features contributed substantially to the maintenance of desirable system hydrology.

Coastal Restoration Goal

The coastal restoration goal for LACPR could be summarized as ***"Achieve ecosystem sustainability in coastal Louisiana to the greatest degree possible."*** This goal would be accomplished through:

- Examination of coastal restoration strategies that contribute to sustainable hurricane risk reduction;
- Inclusion of individual measures of varying sizes to restore and maintain landscape features and essential wetland maintenance processes;
- Identification and programmatic assessment of combinations of individual measures which provide ecosystem-level synergistic benefits;
- Programmatic assessment of the potential of alternative plans to achieve or exceed no-net loss of coastal wetlands;
- Examination of the potential for trade-offs associated with various restoration alternatives (e.g. near-term protection vs. long-term sustainability and fisheries changes vs. deltaic processes).

Two-Tiered Screening and Formulation Process

A two-tiered process was used to develop the coastal restoration alternatives:

- **Tier 1 - Initial Screening of Measures and Formulation of Alternatives** eliminated coastal restoration measures that were not essential to sustaining the integrity of the landscape. The remaining measures were grouped using several different rationales to formulate five primary coastal restoration alternatives in each planning unit.
- **Tier 2 - Screening of Alternatives and Selection of a Representative Alternative** evaluated the five primary coastal restoration alternatives and selected the alternative that best met the criteria of sustaining the existing landscape over a 100-year period to use as a representative landscape.

Tier 1: Initial Screening of Measures and Formulation of Alternatives

The Habitat Evaluation Team considered implementation of measures identified during the development of the State Master Plan. A range of features that could maintain or restore natural deltaic processes and hydrology in coastal Louisiana were considered; these included diversions of the Mississippi River, marsh creation, and maintenance or restoration of ridges, cheniers (oak ridges), and barrier islands. These features were prioritized according to the degree of basin-level benefits they would provide. Factors considered for prioritization included:

- Distance to sediment sources, both riverine and offshore
- Availability of freshwater for sustainability
- Existing structures to aid in sediment confinement during construction
- Average depth of open water areas
- Land/water distribution
- Need for shoreline protection
- Preferred sediment grain size for restoration
- Processes responsible for wetland loss
- Measure of local subsidence
- Potential fisheries impacts
- Measure of flood and infrastructure protection provided by site
- Proximity of pipeline right-of-ways and access for construction
- Overlap with LCA/CWPPRA projects

Ultimately, prioritization was made primarily on the basis of the contribution of the measures to sustaining the integrity of the most critical estuarine regions in each hydrologic basin. Measures that would restore and/or maintain critically important landscape features or marsh areas were given highest priority. Because construction of the most critically important measures would require more sediment than was readily available in many cases, the Habitat Evaluation Team subdivided many of the marsh polygons from the State Master Plan into smaller units that could be separately prioritized. Additional marsh creation areas or erosion reducing measures that were not identified in the State Master Plan were also developed and applied to coastal restoration alternatives R1, R2, and R4, which are described below. Those marsh creation measures assigned the lowest priority were excluded from further analysis.

Five primary alternatives were identified for further analysis at the end of the first tier of screening. See **Table 5-1** below:

Table 5-1. Coastal restoration alternatives as development for initial screening.

Alternative Rationale	PU 1	PU2	PU3a	PU3b	PU4
Alternative relies primarily on diversions off of the Mississippi River. In PUs 1 and 2, the diversions are steady state; in PU3a, the alternative includes diversions that could be either steady state or pulsed.	R1	R1	R1	Not applicable	Not applicable
Alternative relies primarily on “pulsed” flow diversions off of the Mississippi River.	R2	R2	Not applicable	Not applicable	Not applicable
Alternative relies primarily on diversions or water management off of the Gulf Intercoastal Waterway.	Not applicable	Not applicable	R2	Not applicable	Not applicable
Bankline stabilization combined with dedicated marsh creation.	Not applicable	Not applicable	Not applicable	R1	R1
Dedicated marsh creation without bankline stabilization.	Not applicable	Not applicable	Not applicable	R2	R2
State Master Plan	R3	R3	R3	R3	R3
Other coastal restoration measures not identified in the State Master Plan or modified from the State Master Plan (R3).	R4	R4	R4	R4	R4
Louisiana Coastal Area (LCA) *Plan that Best Meets the Objectives*.	R5	R5	R5	R5	R5

A sixth alternative involving a possible major realignment of the lower Mississippi River was identified in Planning Units 1 and 2 for further evaluation. However, this alternative was considered to be beyond the scope of the current effort and could not be adequately evaluated within the scope of this effort. Each of the alternatives developed focus on the use of measures that contribute to estuarine maintenance at a basin scale, namely freshwater diversions, marsh creation using dredged material, ridge/chenier restoration, and barrier island restoration.

Tier 2: Screening of Alternatives and Selection of a Representative Alternative

In the second tier of screening, each of the alternatives as shown in **Table 5-1** above was subjected to a performance analysis over a period of 100 years. The value generated was not a habitat value, but rather a simple gross maximum acreage of wetlands created and/or protected for each alternative for each planning unit over 100 years. From the analysis, the acreages calculated at various points in time were used to develop a performance trend for each alternative. Those plans that resulted in negative acreages, indicating an inability to achieve coastal restoration goals, were dropped from further consideration. The remaining alternatives included R1, R2, and R3 in Planning Units 1 and 2 and R1 in Planning Units 3a, 3b, and 4. From the remaining alternatives in Planning Units 1 and 2, one alternative was chosen as a representative coastal restoration alternative to be carried forward into the analysis as a representative landscape in order to reduce the number of alternative combinations. **Table 5-2** provides a summary of the coastal restoration alternatives for further consideration.

Table 5-2. Summary of coastal restoration alternatives.

Planning Unit	Alternatives Meeting Restoration Goals	Representative Alternatives
1	R1, R2, R3	R2
2	R1, R2, R3	R2
3a	R1	R1
3b	R1	R1
4	R1	R1

Additional Refinement and Tradeoff Analyses of Restoration Plans

While the alternatives selected may represent an optimum outcome for comprehensive coastal restoration, additional analysis and refinement of those plans, and even measures included in other excluded alternatives, could become viable restorations means. As such, each of the alternatives was developed to emphasize a particular strategy for attaining a “sustainable” coastal system and not a specific, well defined plan for authorization and implementation.

Costs, limited sediment supplies, and construction rates, among other factors, dictate that implementation of any of the complete restoration alternatives will require several decades. Restoration must keep up with loss since all plans rely on sustaining the existing landscape. Implementation must also advance in an adaptive fashion in order to permit the formulation and testing of hypotheses regarding the effectiveness of various restoration measures and strategies. Given these factors, any of the alternatives could serve as a starting point for restoration, and would be expected to evolve over time as a consequence of improved understanding of the effectiveness of the various measures. However, the Habitat Evaluation Team believes that achieving sustainability particularly in Planning Units 1, 2, and 3a will require the use of strategically located and operated freshwater diversions that are generally larger than those that have been previously proposed by others. Larger structures provide not only an increased area of influence, but also more flexibility for future operational changes, such as periodic pulsed flows. While the use of freshwater diversions from the Mississippi River as a method of coastal restoration is a very popular issue, technical issues persist as to how well they could potentially perform and how they could be operated.

A major issue remaining to be fully explored is the tradeoff concerning freshwater diversion size and operability. Seasonal, “steady” flow diversion operation is assumed to have a long term adverse impact by over-freshening of brackish to saline habitats and the permanent displacement of associated fisheries and wildlife. Seasonal “pulsed” flow diversion operation, which requires diversion structures to be overbuilt, might cause similar impacts; however, those impacts are assumed to be short term.

Another significant tradeoff component is resource allocation of freshwater between Planning Units 1, 2, and 3a. For most alternatives, the issue of freshwater allocation for diversions can impose operational difficulties or opportunities and induced shoaling maintenance within the navigation channel of the Mississippi River. The “pulsed” alternative provides the most built flexibility regarding optimal operation through adaptive management opportunities.

Structural Measures and Alternatives

Structural measures include raising existing levees and/or building new levees, floodwalls, pumps, gates, and weirs. Levees protect limited portions of the coast that have intense economic development. These measures are intended to significantly reduce risk from the surge and waves associated with a hurricane. Pumping stations reduce flood risk from rainfall, but historically cannot pump out floodwater in the case of a levee breach or significant overtopping. Floodgates crossing water courses and tidal passes are designed to withhold floodwater during storm events, but are generally left open during non-flood events so that navigation or natural ebb and flow of tides and aquatic organisms are not impeded.

Hollow Core Levee Investigation

As part of the ongoing hurricane damage risk reduction work, as well as the LACPR effort, an evaluation of a hollow core concrete levee concept was undertaken. Results of the investigation can be found in Annex 2 of the *Engineering Appendix*.

The concept of the hollow concrete levee system is such that the section fills with water from the bottom as the storm surge rises. The combined weight of the concrete frame and its water-filled voids inside the frame result in a gravity structure designed to resist hydrostatic forces and impact forces from waves and vessel collision. This type of levee has potential as a replacement for more typical earthen levee construction, especially in isolated areas with poor foundations as well as in highly developed areas with limited rights-of-way. This type of measure and opportunities for application will be investigated more thoroughly in subsequent design phases. For the following formulation of structural measures and alternatives, typical earthen levee construction is assumed.

Screening Structural Measures and Alternatives

Considering the large volume of structural measures and alternatives identified during this effort, compared to the LACPR funding limitations and constrained schedule, it was essential that the LACPR team reduce the list of measures under consideration to a manageable number. Early screening helped to refine the number of measures that would be investigated in greater detail and eventually included in alternative plans. More details on the screening of structural measures and alternatives can be found in the *Structural Plan Component Appendix*.

A three-tiered screening process was used to reduce possible structural measures, alignments and alternatives to a more manageable number for further evaluation and consideration across a wide range of stakeholder interests. The screening of structural measures and alternatives, as discussed below, should not be confused with the evaluation, comparison and selection of the final alternative plans.

- **Tier 1** considered preliminary construction costs, constructability, and environmental impacts to screen potential solutions.

- **Tier 2** involved further screening of management measures based on initial hydromodeling results.
- **Tier 3** used a multi-criteria screening process (not to be confused with the multi-criteria decision analysis discussed later in this report) to incorporate a higher level of detailed information based on six attributes.

Tier 1 Screening

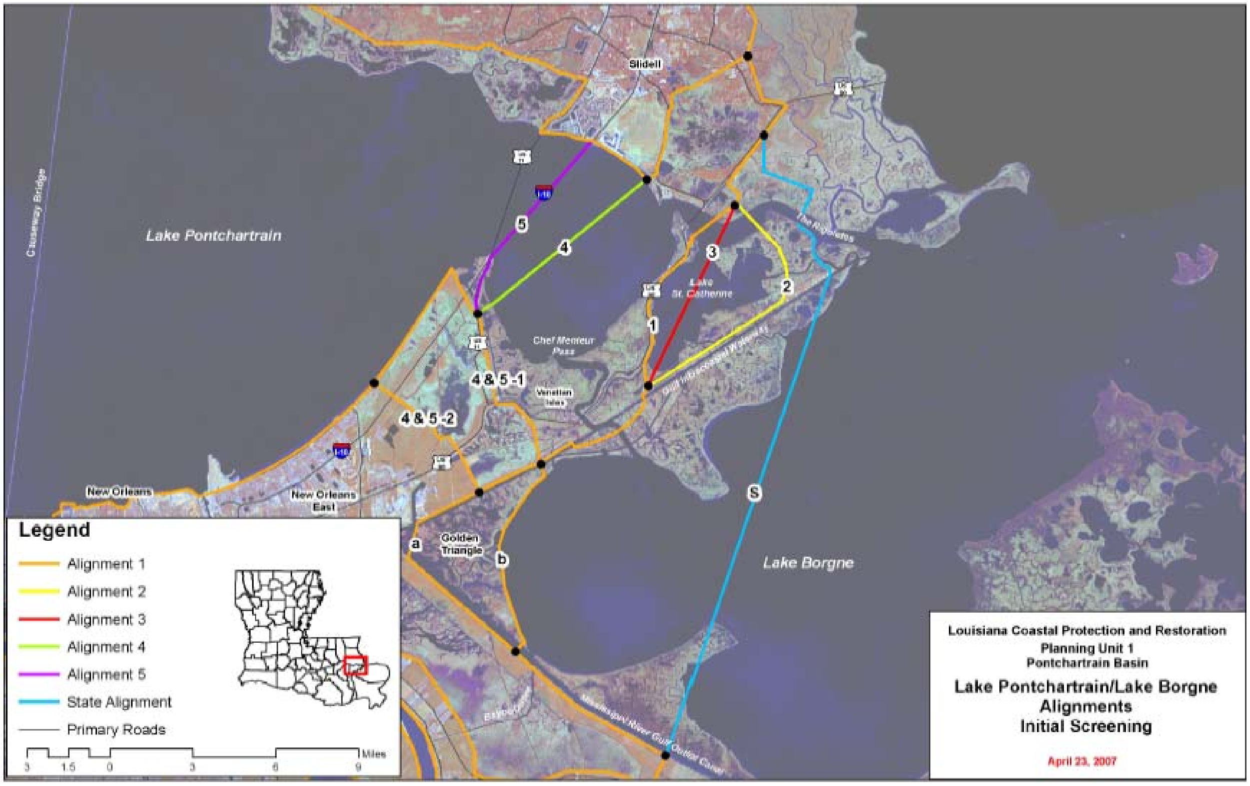
In April and May 2007, the USACE and State teams screened the structural measures identified in the Plan Formulation Atlas. Each measure either “passed” (moved on to the next screening level) or “failed” (dropped from further consideration) based on consideration of potential performance of each compared to other similar measures. Typical to planning efforts, criteria used at this screening level to assess measures and potential performance were mostly subjective with limited quantitative data available. Screening included consideration of the following:

- Extraordinarily high construction costs
- Constructability issues
- Potential for significant induced flooding
- Highly disrupted to existing hydrology (local drainage)
- Significant wetland loss
- High interference with potential restoration plans
- Excessive real estate acquisition issues
- Excessive operations and maintenance costs

The goal in using such criteria is to identify those measures that clearly stand out as poor choices with respect to a particular criterion. Again, the aim of applying these initial screening criteria was to eliminate clearly inferior choices from further consideration. Representative alignments of strategically different structural measures were maintained in order to evaluate tradeoffs through the multi-criteria decision analysis.

The initial screening of structural measures was less formal than the process used to evaluate and identify the final array of alternative plans. This initial screening primarily compared alignments without consideration to the level of risk reduction (e.g. 100-year vs. 1000-year). Alignments were eliminated when another similar alignment could theoretically provide the same level of risk reduction but at a lower cost, with less potential adverse environmental impacts, less real estate requirements, and/or fewer challenges, etc. For example, in Planning Unit 1, the Plan Formulation Atlas presented six different alignments for structures (barriers) to be placed at the Lake Pontchartrain passes. Through this initial screening process, three of the six alignments were eliminated from further consideration, i.e. alignments 3, 4, and 5 as shown **Figure 5-2** below).

Figure 5-2. Initial screening alignments in Planning Unit 1.



Alignment 'a' refers to the levee alignment that would cross the Golden Triangle wetlands at the confluence of the Gulf Intracoastal Waterway and the Mississippi River Gulf Outlet. Alignment 'a' is part of the baseline conditions scheduled to be in place around 2011. Alignment 'b' follows along the edge of the Golden Triangle and Lake Borgne and would provide a secondary line of defense to Alignment 'a.'

Tier 2 Screening

Structural measures that passed the initial screening underwent a second screening once results of the hydromodeling analysis became available and a measure of hurricane surge risk reduction performance could be evaluated. The alternative alignments that passed the Tier 1 screening were further defined by setting design levels (i.e. 100-year, 400-year, and 1000-year). The hydromodeling analysis helped make design comparisons such as open versus closed (gated) tidal passes at The Rigoletes and Chef Menteur, overtopping versus non-overtopping barriers, etc.

The same general criteria as were used in the Tier 1 screening were used in the Tier 2 screening, but could be measured with more detailed quantitative data. For example, open tidal passes were screened out because they performed poorly in comparison to closed tidal passes. In other cases, non-overtopping barriers were eliminated because of undesired water level increases to adjacent areas, high costs and constructability issues. The Tier 2 screening and associated evaluation process also facilitated the development of specific alternatives for further evaluation, including variances to address specific problem areas.

Tier 3 Screening

The resulting set of alternatives, at the three design levels, was further screened once detailed performance data, including hydromodeling results, cost estimates, economic data, and wetland impacts became available. For the third tier screening, a multi-criteria screening process was used to rank each structural alternative based on evaluation data for the six attributes shown in **Table 5-3** below. In order to have comparable scores for each of these attributes across alternatives, values in each were normalized or converted to a scale of 0-1, with a score of 0 being the best performer and score of 1 being the worst performer or having the greatest adverse impact. These individual ratings were then totaled across the attributes to develop a composite value or score for each alternative. As such, the alternatives with the lower scores are preferred. However, in identifying the final array of alternatives for detailed evaluation and comparison, not only were the best performers in this analysis selected, but also those alternatives representing a cross section of stakeholder interests in strategically different alternatives or concepts.

Table 5-3. Attributes used to screen structural alternatives.

Attribute	Description
Cost Effectiveness	Ratio of present value costs/average annual risk reduction
Present Value Costs	Present value at 2025 for life-cycle costs
Average Annual Flood Damages	With-project damages
Population Exposed	People inundated at inundation frequency
Construction Period	Years required to complete initial construction
Direct Impact – Wetlands	Wetland acreage impacted by proposed levees

The following sections describe (by planning unit) the screening and the identification of structural measures that are combined with nonstructural and coastal restoration management measures to form comprehensive hurricane risk reduction strategies.

Summary of Screening of Structural Alternatives by Planning Unit

Based on screening, and in consideration of the need to investigate a range of potential ways to reduce the risk from hurricane surge, 40 structural alternatives across the five planning units were selected for detailed evaluation in combination with nonstructural and coastal restoration measures or alternatives. The best performers of these alternatives by planning unit will eventually be combined to form comprehensive coast wide alternative plans.

Planning Unit 1

The Plan Formulation Atlas identified two primary structural strategies in Planning Unit 1. One strategy includes raising the existing levees on the south shore of Lake Pontchartrain to a higher level of risk reduction and adding structural protection elements in Laplace and on the north shore of Lake Pontchartrain, referred to as the **High Level alternatives (designated by 'HL')**. By contrast, the second strategy or **Lake Pontchartrain Surge Reduction alternatives (designated by 'LP')** include the construction of a weir barrier with gated structures across the two tidal passes connecting Lake Pontchartrain with the Gulf of Mexico. This alternative also includes consideration of additional structural protection elements in Laplace and the on the north shore of Lake Pontchartrain.

Common to both alternatives are structural elements in New Orleans East, portions of St. Bernard Parish, the upper portion of Plaquemines Parish and a floodgate across the Gulf Intracoastal Waterway (GIWW). In addition, alternatives in Planning Unit 1 will need to be refined in order to reduce impacts to the coast of Mississippi; LACPR must either eliminate or satisfactorily mitigate any remaining regional impacts.

Following the tiered screening process, ten structural alternatives were selected for further analysis in Planning Unit 1.

Planning Unit 2

The Plan Formulation Atlas identified four primary strategies for structural risk reduction within Planning Unit 2. The levee alignments included the GIWW levee alignment, Highway 90 levee alignment, swamp alignment, and two alignments along the West Bank interior. Through initial screening, in which preliminary construction costs as well as direct and indirect environmental impacts and hydrologic performance were considered, the number of primary strategies was screened to three, with numerous variants identified.

The most significant change to the initial strategies included modification of the swamp alignment and Highway 90 alignment, combining these to form the **ridge alternatives (designated by 'R')**. Three variations in the **GIWW levee alternatives (designated by 'G')** were considered including structural risk reduction for Lafitte and variations where the levee ties into the Mississippi River Levee System. The **West Bank alternatives (designated as 'WBI')** include improvement to, or extension of the existing West Bank levee and construction of a sector gate on the GIWW in Bayou Barataria at the confluence with the Algiers and Harvey Canals. Common to the three basic alignments is a ring levee encompassing Golden Meadow and Larose.

Following the tiered screening process, 13 structural alternatives were selected for further analysis in Planning Unit 2.

Lower Plaquesmines Parish (Part of both Planning Unit 1 and 2)

The Plan Formulation Atlas presented four options for increased risk reduction in Plaquemines Parish:

1. **Ring Levees/Spillways (PL-RS) –** This option proposes spillways in combination with ring levees in multiple locations in Plaquemines Parish. The spillway concept was envisioned to reduce hurricane surge in the New Orleans area and Plaquemines Parish by degrading sections of the existing Plaquemines Parish levees to allow storm surge transfer between Breton Sound and Barataria Bay areas. Highway bridges would be constructed over degraded levee reaches.
2. **Closed Ring Levee System (PL-RL) –** This option includes a series of basins (ring levees) that would provide an increased level of risk reduction to critical facilities and more densely populated areas of lower Plaquemines Parish. Levee sections outside the closed ring levee areas would remain at existing height.
3. **Federal Levee Alignment (PL-FL) –** This option proposes to raise the height of all Federal levees in lower Plaquemines Parish to the 100-year design level and to leave the non-Federal levees at existing height.
4. **Existing Levee Alignment (PL-EL) –** This option would incorporate non-Federal levees in Plaquemines Parish into the Federal levee system and raise the height of all existing levees in lower Plaquemines Parish.

As a result of the high cost and the potential surge increase in Louisiana and Mississippi created by levees in this area, both the State Master Plan stakeholder process and the USACE screening process eliminated most of the structural measures in lower Plaquemines Parish. The spillway concept was modeled; however, results are inconclusive at this time. The spillway concept appears to have some merit but further study is needed.

Planning Unit 3a

The two primary structural alternative strategies considered for Planning Unit 3a are the **Morganza to the Gulf alternatives (designated by 'M')**, which are variations on the currently proposed 100-year Morganza to the Gulf project authorized by the Water Resources Development Act of 2007, and a set of **GIWW alternatives (designated by 'G')**, which would provide a second line of defense further inland along the Gulf Intracoastal Waterway.

Alternatives include: extending the proposed Morganza alignment westward to Morgan City and into the Atchafalaya basin; tying the proposed Morganza alignment into high ground to the west of Houma with a ring levee around Morgan City; and using the Morganza levee as a first line of defense at a 100-year design level and then providing a second levee alignment further inland, along the GIWW, to prevent inner flooding around Houma at a 400-year and 1000-year frequency design, and again including a ring levee around Morgan City.

Following the tiered screening process, four structural alternatives were selected for further analysis in Planning Unit 3a.

Planning Unit 3b

The primary levee alignment strategies considered in Planning Unit 3b included two parallel alignments extending from Morgan City west across Vermilion Bay. The southern alignment follows the **GIWW** and extends into Planning Unit 4. The northern alignment, referred to as the **Franklin to Abbeville alternatives (designated by 'FA')**, provides a ring levee around Patterson and a continuous levee from Patterson, around Franklin and Baldwin and tying to high ground to the west of Abbeville. A third levee alignment strategy considers **ring levees (designated by 'RL')** around concentrated population centers, including Patterson, Franklin, Baldwin, New Iberia, Erath, Delcambre and Abbeville.

Following the tiered screening process, six structural alternatives were selected for further analysis in Planning Unit 3b.

Planning Unit 4

The levee alignment strategies for this planning unit are relatively similar for the two continuous levees extending along the GIWW westward from near Vermilion Bay to the Calcasieu River just below Lake Charles, with a separable reach west of the river. The first of these **GIWW alternatives (designated as 'G')** joins with the GIWW alignment in Planning Unit 3b. The second GIWW alignment has a return to high ground to the west of the Vermilion River so that this alternative can be evaluated as "stand alone." This alignment has also been evaluated at a 12-foot levee height, performing essentially as an overtopping weir. An additional alignment strategy consists primarily of a series of **ring levees (designated by 'RL')** to the east and west of Lake Charles. Common to all three is a series of small levees within Lake Charles to separate the river from the land.

Following the tiered screening process, seven structural alternatives were selected for further analysis in Planning Unit 4.

Summary of Structural Alternatives

Table 5-4 provides a summary of the structural alternatives to be carried forward into the LACPR analysis. Further explanation of codes and full descriptions of alternatives can be found in **Table 5-6** through **Table 5-12** in the section on *Array of Alternatives to be Evaluated and Compared*.

Table 5-4. Summary of structural alternatives.

Planning Unit 1	Planning Unit 2	Planning Unit 3a	Planning Unit 3b	Planning Unit 4
LP-a-100-1	WBI-100-1	M-100-1	G-100-1	G-100-1
LP-a-100-2	WBI-400-1	M-100-2	F-100-1	G-100-2
LP-a-100-3	R-100-2	G-400-2	F-400-1	G-400-3
LP-b-400-1	R-400-2	G-1000-2	F-1000-1	G-1000-3
LP-b-400-3	R-100-3		RL-100-1	RL-100-1
LP-b-1000-1	R-400-3		RL-400-1	RL-400-1
LP-b-1000-2	R-100-4			RL-1000-1
HL-a-100-3	R-400-4			
HL-a-100-2	R-1000-4			
HL-b-400-3	G-100-1			
	G-100-4			
	G-400-4			
	G-1000-4			

Notes:
LP = Lake Pontchartrain (barrier-weir)
HL = High Level.
WBI = West Bank.
R = Ridge
G = GIWW
M = Morganza to the Gulf
F = Franklin to Abbeville (inland of the GIWW)
RL = Ring Levee

Nonstructural Measures and Alternatives

Nonstructural risk reduction measures do not attempt to change the nature of a storm event or a flood profile. Nonstructural measures reduce the consequences of flooding by limiting the exposure of economic assets to damages by changing the nature of the assets in some way. Types of nonstructural measures include wet and dry flood proofing, flood warning, raising-in-place by lifting on pilings or placing on fill, relocations of property improvements, and buyouts of properties. This group of measures includes risk management land use practices that offer strategies for reducing exposure to storm hazards by influencing development within the floodplain, in combination with, or sometimes instead of, structural measures.

For the purposes of the LACPR plan formulation, buyout/relocation of structures and elevation of structures are considered to be the most viable nonstructural measures for overall applicability across South Louisiana. This generalized determination was made on the basis of flood depth and hydrodynamic force associated with hurricane storm surges as well as on the breadth of the study.

All nonstructural flood proofing measures can be effective in reducing damages from floods for which the measure was designed. However, the only way to ensure complete safety from storm or flood risk is either through buyout and demolition of structures or relocating structures to a site outside the floodplain. Nonstructural measures, such as buyouts and relocations, can provide opportunities for alternate uses of the vacated flood plain, such as ecosystem restoration, recreational development, or urban green space if sufficient contiguous parcels are purchased for evacuation.

Nonstructural measures also contribute to community sustainability and economic recovery where the measures protect existing residential structures, commercial buildings, and especially critical facilities that provide a base for emergency response and a post-storm foothold for recovery.

The scope of the nonstructural plan component for LACPR entailed three aspects:

1. Formulation of nonstructural measures by applying buyouts and/or raising-in-place of structures;
2. An assessment of protecting critical facilities; and
3. Identification of potential nonstructural demonstration projects.

More details on the nonstructural features of LACPR can be found in the *Nonstructural Plan Component Appendix*.

Formulation of Nonstructural Measures

The physical aspects of storms are a major consideration when formulating nonstructural measures at specific sites. Certain nonstructural measures function better given defined flooding conditions or when considering other interests. For example, the only reliable nonstructural measure under high-velocity surge conditions is buyout of property and permanent evacuation of the population at risk. Conversely, flood-proofing, such as raising-in-place either on fill or piers works well for low-velocity flooding conditions. Raising structures in place is effective when an interest exists in maintaining a local tax-base and when flooding conditions and structural integrity warrant its application, so long as elevating does not put the structure at further risk in the wind field. Also, relocation of structures and population into clusters at flood-free sites can address both risk reduction and community cohesion concerns.

An evaluation of the entire southern Louisiana coast was conducted to identify opportunities for risk reduction and to establish areas for further in-depth analysis. Nonstructural measures were formulated at the planning unit level. The intention of this effort was to establish a programmatic approach to implementation of nonstructural measures in a comprehensive and systematic manner.

Nonstructural measures can be developed into stand-alone alternatives or can be combined with other types of risk reduction measures as one line in a multiple lines of defense strategy for reducing and managing hurricane risks. The LACPR team formulated nonstructural measures within the following categories:

- **Stand-alone measures** to compete against structural measures within planning units and at similar levels of risk reduction;
- **Complementary measures** in the residual floodplains of structural measures in order to provide a uniform level of risk reduction throughout the planning unit;
- **Site specific measures** to compete with levee segments that could be considered increments to the overall levee system; and
- **Redundant measures** as a concept plan within the New Orleans area levee system to address the need for community resiliency and system redundancy.

Formulation Criteria

In general, the team based the formulation of nonstructural measures on the following decision criteria, which indicate a high degree of flood risk:

- **Storm surge areas of high surge velocity**: Areas noted as “high-velocity” (V) zones by FEMA were investigated for population and property with the intent of reducing or eliminating exposure using buyout and permanent relocation.

- **Depth of inundation areas of deep flooding**: Areas of flood inundation were investigated for nonstructural measures such as raising-in-place for depths of inundation less than 14 feet. Where inundation depths are 14 feet or higher, buyout/permanent evacuation measures apply.

Stand-alone and complementary measures are based on both criteria. Site specific measures are based on depth of inundation only. Redundant measures are based on raising all low-lying structures within the New Orleans levee system to one foot above mean sea level.

<u>Velocity Zones</u>

Velocity zones (Vzones) were spatially associated with census blocks to identify high-risk areas. Census blocks were identified and combined for processing through the geodatabase. Outputs of the processing included an estimate of the number of structures and the population impacted by various flood events, as well as an estimate of damages to economic assets from those flood events. These areas were targeted for relocation/permanent evacuation based on the established decision criteria. Therefore, benefits and costs were developed for relocations to the baseline structure inventory for the designated census blocks falling within FEMA's Vzones. Buyouts of these areas would eliminate the risk to people and assets.

<u>Depth of Inundation</u>

Depth of inundation was used as another indicator of risk. The base condition assumes that the improvements to the metropolitan New Orleans levee system as prescribed in the Fourth Emergency Supplemental Appropriation are complete and provide protection from overtopping to the 90 percent confidence level of the 100-year flood stage. Hydrologic stages, upon which some nonstructural measures are formulated based on inundation, assume no failure or breaching. Overtopping is assumed above the 90 percent confidence stage of the design level of performance.

Flood depths from the 90 percent confidence stages of 100-year, 400-year, and 1000-year storm events were aggregated into practical ranges of 1 – 2 feet, 3 – 6 feet, 7 – 13 feet, and depths of 14 feet and higher based on the stage of the event as compared with the mean ground elevation of each census block. The base condition flood stages were referenced for formulation of stand-alone and site specific nonstructural measures. Structural and coastal measures' residual floodplain flood stages were the basis for formulation of complementary nonstructural measures. The redundant nonstructural measure for metropolitan New Orleans was formulated without regard to flood stage.

The areas identified to be flooded from depths of 1 – 2 feet were removed from further consideration with the expectation that first floor corrections, averaging two feet in the structure database, would eliminate these areas from actual damage. The areas identified as flooding 3– 13 feet qualified for raising-in-place with the expectation that the structural integrity of the structures would be determined during the implementation phase. Those census blocks that experienced depths of flooding of 14 feet or greater qualified for buyouts/permanent evacuation based on the decision criterion that lifting a structure above 13 feet would elevate it into an undesirable wind field and would violate best practices as set forth in the July 2006, FEMA technical manual, Publication 550, *Recommended Construction for the Gulf Coast, Building on Stronger and Safer Foundations.*

The FEMA Publication 550 offers the rationale for the raising-in-place criterion decision. The following excerpt is taken from the referenced manual: "This manual contains closed foundation designs for elevating homes up to 8 feet above ground level and open foundation designs for elevating homes up to 15 feet above ground level. These upper limits are a function of constructability limitations and overturning and stability issues for more elevated foundations." The nonstructural analysis used an upper limit of 14 feet for elevation because of the uncertainty of where the bottom of the lowest horizontal member of the structure frame might actually be.

Using 14 feet as the upper limit was considered to be a conservative approach to the analysis but could be refined in subsequent studies.

Stand-alone Measures

Using the decision criteria previously described, planning units were evaluated for location of velocity zones and depth of inundation. Stand alone nonstructural plans were formulated with the following measures:

1) Buyout of delineated FEMA velocity zones across the entire planning unit.
2) Buyout of all structures within census blocks not in velocity zones which demonstrate a depth of inundation of 14 feet or greater across the entire planning unit.
3) Raise-in-place for all structures in census blocks which demonstrate a depth of inundation between three and 13 feet across the entire planning unit.

Stand-alone nonstructural plans with these combined measures were formulated for three levels of risk reduction to the 100-year, 400-year, and the 1,000-year risk reduction levels as shown in **Table 5-5** below.

Table 5-5. Summary of stand-alone nonstructural alternatives.

Level of Risk Reduction	Planning Unit 1	Planning Unit 2	Planning Unit 3a	Planning Unit 3b	Planning Unit 4
100-year	NS-100	NS-100	NS-100	NS-100	NS-100
400-year	NS-400	NS-400	NS-400	NS-400	NS-400
1000-year	NS-1000	NS-1000	NS-1000	NS-1000	NS-1000

Complementary Measures

Nonstructural measures were also formulated in the residual floodplain of each structural/coastal measure to conform to the level of risk reduction provided by the structural measure. Decision criteria were applied in the same way as in the stand-alone measure formulation. As a result, the nonstructural measures formulated in the residual floodplain of the structural measures share the same components of velocity zone buyouts, buyout of structures whose census blocks demonstrate deep flooding of 14 feet or greater, and raising-in-place of structures whose census blocks demonstrated flooding between three and 13 feet. The magnitude and distribution of nonstructural measures based on depth of flooding changes with the structural measure considered.

When the complementary nonstructural measures are combined with the structural/coastal alternatives listed in **Table 5-4** in the section on *Summary of Screening of Structural Alternatives by Planning Unit*, the comprehensive alternative plans are formed. Comprehensive plans are designated by adding ‘C-’ in front of the structural/coastal alternative codes. The comprehensive plans are listed in **Table 5-7** through **Table 5-11** in the section on *Array of Alternatives to be Evaluated and Compared*.

Site Specific Measures

Levee segments that could be considered increments to the overall levee system were identified for the formulation of competing nonstructural measures for a cost effectiveness analysis. Nonstructural measures for specific sites conformed to the decision criterion of depth of inundation previously described and were formulated with the corresponding level of risk reduction provided by the levee segment. Nonstructural measures were formulated for the following sites:

Planning Unit 1

1. Slidell Ring Levee
2. Northshore Levee
3. Laplace Levee
4. Oakville Levee
5. Plaquemines Levee

Planning Unit 2

1. Lafitte Levee
2. Golden Meadow Levee
3. Des Allemands Levee
4. Plaquemines Levee

The team is still in the process of formulating site specific measures for the tradeoff analysis in Planning Units 3a, 3b, and 4. The evaluation of these tradeoffs will be made before release of the final report.

Redundant Measures

Redundancy of risk reduction measures is a critical aspect of creating a fail-safe risk reduction system. As a redundant feature, nonstructural measures contribute to management of the risk of interior flooding, whether from rainfall or from hurricane surges that may exceed the design capacity of the risk reduction system. An added benefit of this redundant system is found in the timing of implementation. Because nonstructural measures can typically be implemented in less time, they would reduce flood risk prior to completion of structural measures. Upon completion of the structural measures, the combined measures would provide redundancy to the flood control system.

The existing levee system surrounding the New Orleans area allowed the team to apply the concept of redundancy as a multiple lines of defense strategy for risk reduction. The development of a Redundant System Nonstructural Plan for the New Orleans area addresses the City's expressed interest in a achieving a resilient and sustainable economic recovery and provides an example of the magnitude of resources that would be required to affect a "fail-safe" system in the most urban of areas along the Louisiana coast.

The Redundant System Nonstructural Plan is independent of the stand-alone and complementary nonstructural measures to be evaluated along with the coastal and structural alternatives. This concept plan entails raising-in-place of all eligible existing and projected future structures within the New Orleans metropolitan levee system under the two land use/population growth scenarios used in the evaluation of all LACPR plans.

In total a plan for elevating all structures below +1 foot mean sea level within the New Orleans levee system to +1 foot mean sea level would cost between $23 and $28 billion. This plan would impact between 160,000 to 230,000 structures and an associated population between 320,000 and 460,000 residents. The levee system and coastal features would provide risk reduction from storm surge. The Redundant System Nonstructural Plan would provide redundant security to the City's economic assets from any flooding source.

Protection of Critical Facilities

One way to create resiliency within the communities of South Louisiana is to protect vulnerable public and private facilities that are critical to the health and safety of the resident population, especially in the aftermath of storms. Critical facilities are related to critical actions. The definition of a critical action is "any action for which even a slight chance of flooding would be too great."

Over 1,500 facilities have been identified within the LACPR planning area as meeting the critical action definition by using FEMA's Hazard U.S.-Multihazard (HAZUS-MH) database. For LACPR, critical facilities are defined as hospitals, police and fire protection facilities, water treatment facilities, city halls, emergency operations centers, and schools that could serve as evacuation centers. The assumption implicit to the critical facilities analysis is that privately-owned, profit-based industries, such as refineries and power plants, have within their basic operating budgets accommodations for emergency response and recovery so that this category of facilities would not require Federal support for protection.

The desired base flood elevation for critical facilities as stated in Executive Order 11988 is outside the 500-year floodplain or protected to the 500-year stage as a minimum requirement. Many critical facilities in southern Louisiana are subject to high velocity storm surge or deep inundation, indicators of a high degree of risk. However, in order to best serve their surrounding communities, it may be important that these facilities remain at their present locations.

Protection of critical facilities can be addressed through either relocation or flood proofing. Depth of inundation and surge velocity were used to determine the preferred measure. Flood proofing was only considered for structures subject to water depths up to six feet. For structures that had water depths greater than six feet, relocation was selected as the preferred nonstructural measure. Any critical facility that is located within a "V" zone or extreme high hazard area was subject to relocation and buyout. In total, 600 structures would be eligible for flood proofing or relocation based on depth of flooding at an estimated total cost of $3.2 billion. More information on the critical facilities analysis can be found in the *Nonstructural Plan Component Appendix*.

Potential Demonstration Projects

The nonstructural evaluation identified potential demonstration projects of specific size and location where nonstructural measures could be implemented in the near-term. The development of demonstration projects requires close coordination with local communities, the State, Federal and local agencies, and supports local desires for risk reduction and economic recovery. Demonstration projects are intended to discover the challenges and opportunities that exist for future collaboration among the USACE, other agencies, and local governments in implementing nonstructural measures. Some potential demonstration projects may be located within the City of New Orleans and St. Bernard Parish in Planning Unit 1; in Delcambre in Planning Unit 3b; and in Calcasieu Parish in Planning Unit 4. More details on these demonstration projects can be found in the *Nonstructural Plan Component Appendix*.

Additional Implementation Considerations

Nonstructural measures can be implemented incrementally, on a house-by-house basis, or programmatically, across whole neighborhoods or communities. Less time may be required to implement nonstructural measures as compared with implementation of large-scale structural measures. The benefits of nonstructural measures are realized immediately upon implementation to each structure affected.

Prior to implementation of nonstructural measures or plans, consideration should be given to the following:

- **Structural integrity:** Determine whether structures (e.g. buildings) possess the integrity to be lifted or retrofitted for nonstructural measures.
- **Other agency involvement:** Implementation priority should be given to areas where the potential to collaborate with other agencies is high and nonstructural measures are compatible with other Federal, State, or local initiatives such as ecosystem restoration, FEMA acquisitions, or local initiatives for preserving communities/living cultures.

Except for flood warning systems, nonstructural measures generally take effect on privately-owned property and require that the non-Federal sponsor take an active role in implementation. Nonstructural measures can be either implemented voluntarily or mandatorily based on the position of the non-Federal sponsor. Implementation of measures to protect critical facilities would require close coordination with FEMA's Public Assistance and Hazard Mitigation Grant Programs.

Since nonstructural measures may ultimately be a key component to reducing long-term risks and supporting sustainable redevelopment, a strategy has been developed for programmatic implementation of nonstructural measures. The rationale and strategy for the program is described in Attachment 1 of the *Nonstructural Plan Component Appendix*.

Array of Alternatives to be Evaluated and Compared

Once the three screenings were complete, the team developed alternative plans with differing combinations of the remaining structural, nonstructural, and coastal restoration components for each of the five planning units. The alternative plans were formulated to present strategically different options for providing solutions to identified flooding problems. Comparison of the outputs and effects of these different types of actions, including the no action alternatives, will allow for identification and documentation of tradeoffs to consider in the decision making process.

The 109 alternatives fall into one of five categories:

- **No action** (one alternative in each planning unit).
- **Coastal restoration only** (three alternatives each in Planning Units 1 and 2 and one alternative each in Planning Units 3a, 3b, and 4.).
- **Coastal restoration with stand-alone nonstructural components** (three alternatives in each planning unit).
- **Coastal restoration with structural components** (between four and 13 alternatives in each planning unit).

- **Comprehensive plans** are combinations of coastal restoration, structural measures, and complementary nonstructural measures which generally provide a uniform level of risk reduction for hurricane surge throughout all areas in the planning unit. The complementary nonstructural measures were formulated in the residual floodplains not protected by structural measures (same number as coastal restoration with structural components above).

Other than the no-action alternative, all of the alternatives require active maintenance of the coast at the existing level of risk reduction, i.e. sustain (or maintain) the existing landscape. **Table 5-6** provides a guide to the codes used to refer to the alternatives that were evaluated. **Table 5-7** through **Table 5-11** provides more detailed descriptions of each alternative and **Figure 5-3** through **Figure 5-31** contain example structural alignments and various types of alternatives. **Table 5-12** provides a summary of the alternatives that were evaluated in each planning unit by category.

Table 5-6. Guide to LACPR alternative codes.

Primary Code	Primary Code Description	Planning Unit	Variation Code	Variation Code Description
R#	Coastal restoration alternative	**All Planning Units**	-100-	100-year design level
NS-	Nonstructural alternative		-400-	400-year design level
C-	Comprehensive plan (contains coastal, nonstructural, and structural components)		-1000-	1000-year design level
LP-	Lake Pontchartrain Surge Reduction Plan (includes barrier-weir with surge gates across The Rigolets and Chef Menteur Pass)	**Planning Unit 1** (e.g. PU1-LP-a-100-1)	-a-	Golden Triangle alignment at the confluence of the GIWW and MRGO.
			-b-	Alignment at the edge of the Golden Triangle and Lake Bornge
HL-	High Level Plan (raise existing levees)		-1	Primary alignment-All PU1 primary alternatives include the Lake Pontchartrain and Vicinity levees and upper Plaquemines levees. The primary alignments for ‘LP’ also include a barrier-weir across the passes of Lake Pontchartrain with a tieback to high ground east of Slidell.
			-2	Primary alignment (-1) plus Northshore and Westshore levees.
			-3	Primary alignment (-1) plus Slidell and Westshore levees.
WBI-	West Bank Interior Plan.	**Planning Unit 2** (e.g. PU2-WBI-100-1)	-1	Primary alignment -All PU2 primary alignments include West Bank and Vicinity levees with new sector gate and Larose to Golden Meadow levees. Primary alignments for ‘R’ and ‘G’ also include Lafitte ring levees.
R-	Ridge Alignment Plan (parallel to ridges along the West Bank of the Mississippi River and Bayou Lafourche.		-2	Primary alignment (-1) plus Boutte levee.
G-	GIWW Alignment Plan		-3	Primary alignment (-1) plus Boutte and Des Allemands levee.
			-4	Primary alignment (-1) plus Boutte, Des Allemands, and Bayou Lafourche levees.
M-	Morganza levee alignment	**Planning Unit 3a** (e.g. PU3a-M-100-2)	-1	Morganza alignment with tieback to high ground west of Morgan City
G-	GIWW Alignment Plan with Morganza Levee at 100-year design		-2	Morganza alignment with tieback to high ground south of Thibodaux and ring levee around Morgan City
G-	GIWW levee alignment	**Planning Unit 3b** (e.g. PU3b-G-100-1)	-1	Primary alignment (no variations to primary alignments in PU3b)
F-	Franklin to Abbeville alignment (inland of the GIWW)			
RL-	Ring levee alignment			
G-	GIWW levee alignment	**Planning Unit 4** (e.g. PU4-RL-400-1)	-1	For the ‘G’ alignments, the primary alignment follows the GIWW across the planning unit boundaries.
RL-	Ring levee alignment		-2	GIWW alignment with tieback to high ground near Kaplan.
			-3	GIWW alignment with the levee set at a height of 12 feet.

Alternatives in Planning Unit 1

The 27 alternatives in Planning Unit 1 are described in **Table 5-7**.

Table 5-7. Planning Unit 1 alternatives.

Category	Alternative	Alternative Description
No Action	PU1-0	No action (without project) alternative.
Coastal Restoration Only	PU1-R1, R2, and R3	Sustain coastal landscape through restoration including shoreline protection, marsh creation, and diversions. R1 proposes steady state diversions while R2 proposes pulsed diversions. R3 is as proposed in the State Master Plan.
Coastal Restoration and Nonstructural Measures	PU1-NS-100, -400, and -1000	Sustain coastal landscape through restoration. Implement comprehensive 100-year, 400-year or 1000-year nonstructural measures.
Coastal Restoration and Structural Measures	PU1-LP-a-100-1	Sustain coastal landscape through restoration and construct barrier-weir and levees to reduce risk to the Lake Pontchartrain area. Raise upper Plaquemines levees to 100-year level of risk reduction.
	PU1-LP-a-100-2	Sustain coastal landscape through restoration and construct barrier-weir and levees to reduce risk to the Lake Pontchartrain area. Raise upper Plaquemines levees and construct new levees around Laplace and across the Northshore to the 100-year level of risk reduction.
	PU1-LP-a-100-3	Sustain coastal landscape through restoration and construct barrier-weir and levees to reduce risk to the Lake Pontchartrain area. Raise upper Plaquemines levees and construct new levees around Laplace and Slidell to the 100-year level of risk reduction.
	PU1-LP-b-400-1	Sustain coastal landscape through restoration and construct barrier-weir and levees to reduce risk to the Lake Pontchartrain area. Raise Lake Pontchartrain and Vicinity and upper Plaquemines levees to 400-year level of risk reduction.
	PU1-LP-b-400-3	Sustain coastal landscape through restoration and construct barrier-weir and levees to reduce risk to the Lake Pontchartrain area. Raise Lake Pontchartrain and Vicinity and upper Plaquemines levees and construct new levees around Laplace and Slidell to the 400-year level of risk reduction.
	PU1-LP-b-1000-1	Sustain coastal landscape through restoration and construct barrier-weir and levees to reduce risk to the Lake Pontchartrain area. Raise upper Lake Pontchartrain and Vicinity and upper Plaquemines levees to 1000-year level of risk reduction.
	PU1-LP-b-1000-2	Sustain coastal landscape through restoration and construct barrier-weir and levees to reduce risk to the Lake Pontchartrain area. Raise upper Lake Pontchartrain and Vicinity and upper Plaquemines levees and construct new levees around Laplace and across the Northshore to the 1000-year level of risk reduction.

Category	Alternative	Alternative Description
	PU1-HL-a-100-3	Sustain coastal landscape through restoration and construct high level plan providing 100-year design level of risk reduction to Laplace, upper Plaquemines, and Slidell.
	PU1-HL-a-100-2	Sustain coastal landscape through restoration and construct high level plan providing 100-year design level of risk reduction to Northshore of Lake Pontchartrain, upper Plaquemines, and Laplace.
	PU1-HL-b-400-3	Sustain coastal landscape through restoration and construct high level plan providing 400-year design level of risk reduction to Southshore of Lake Pontchartrain, Laplace and Slidell.
Comprehensive (Coastal, Structural, and Nonstructural)	PU1-C-XX-x-xxx-x	Structural/coastal alternatives are made comprehensive by adding complementary nonstructural measures to reduce residual risk in areas without structural risk reduction measures. Comprehensive alternatives are noted by a “C-“ in front of the structural/coastal alternative code.

Figure 5-3. Planning Unit 1 – example coastal restoration plan.

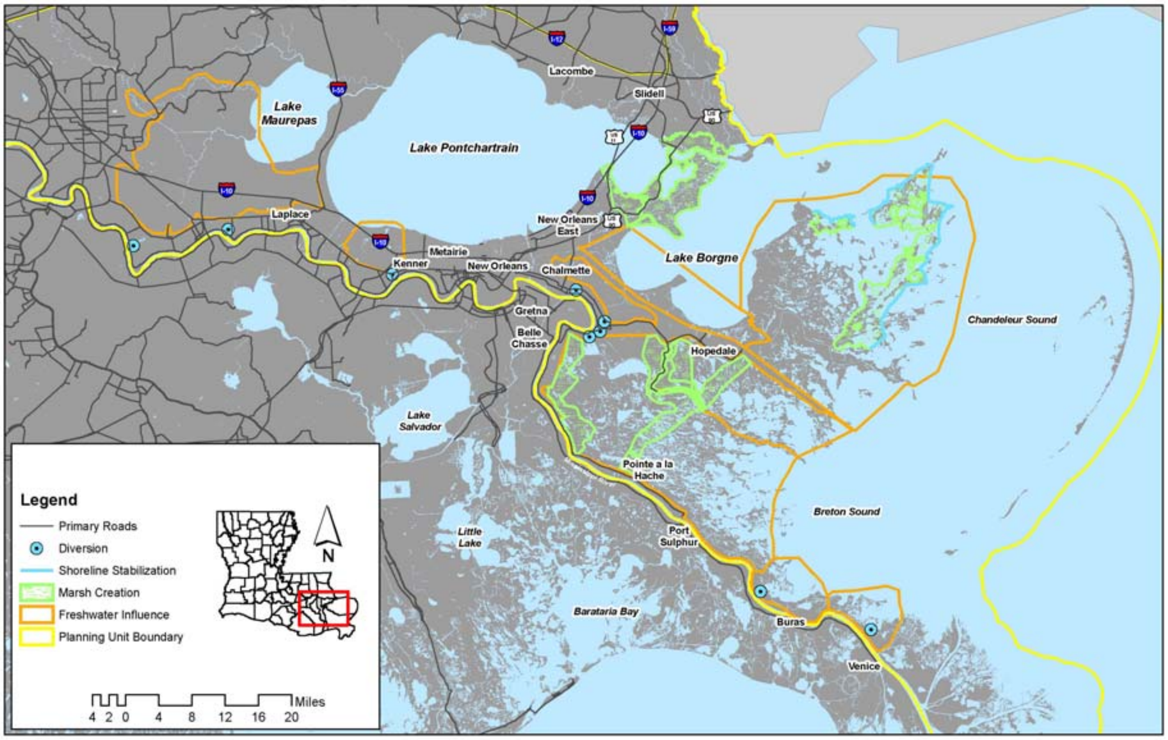


Figure 5-4. Planning Unit 1 – example nonstructural plan.

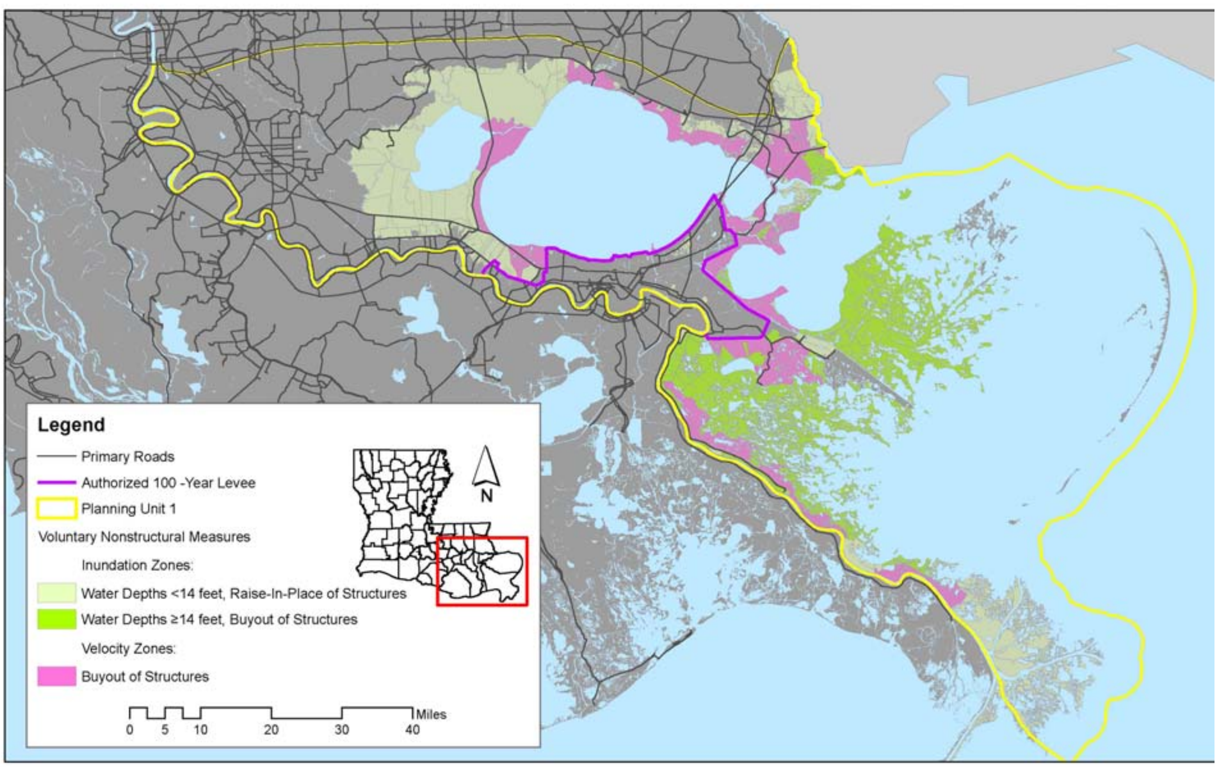


Figure 5-5. Planning Unit 1 – example high level alignment.

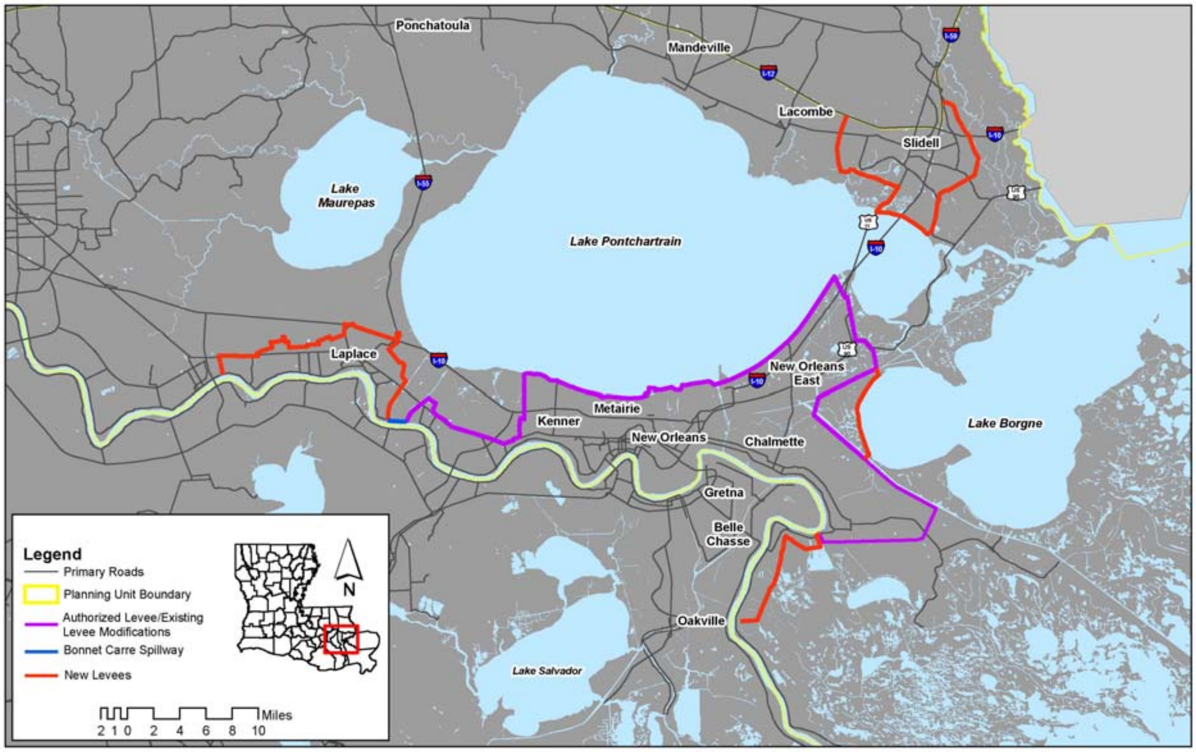


Figure 5-6. Planning Unit 1 – example Lake Pontchartrain surge reduction alignment.

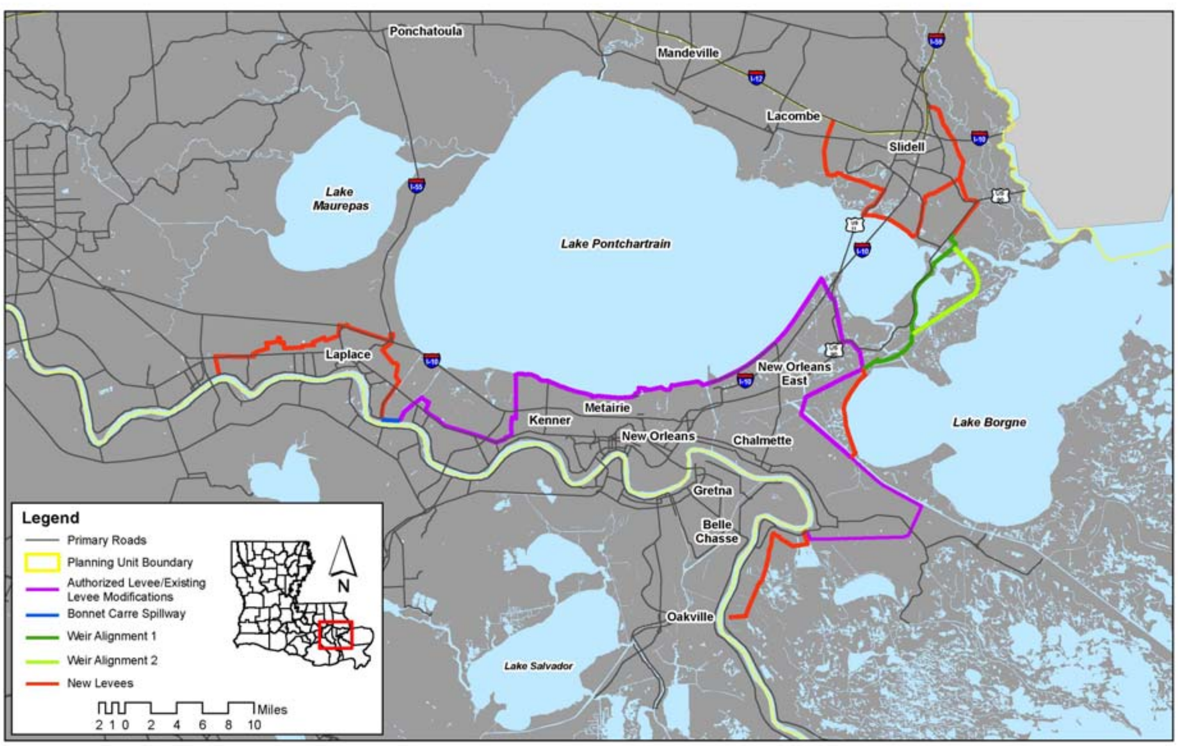
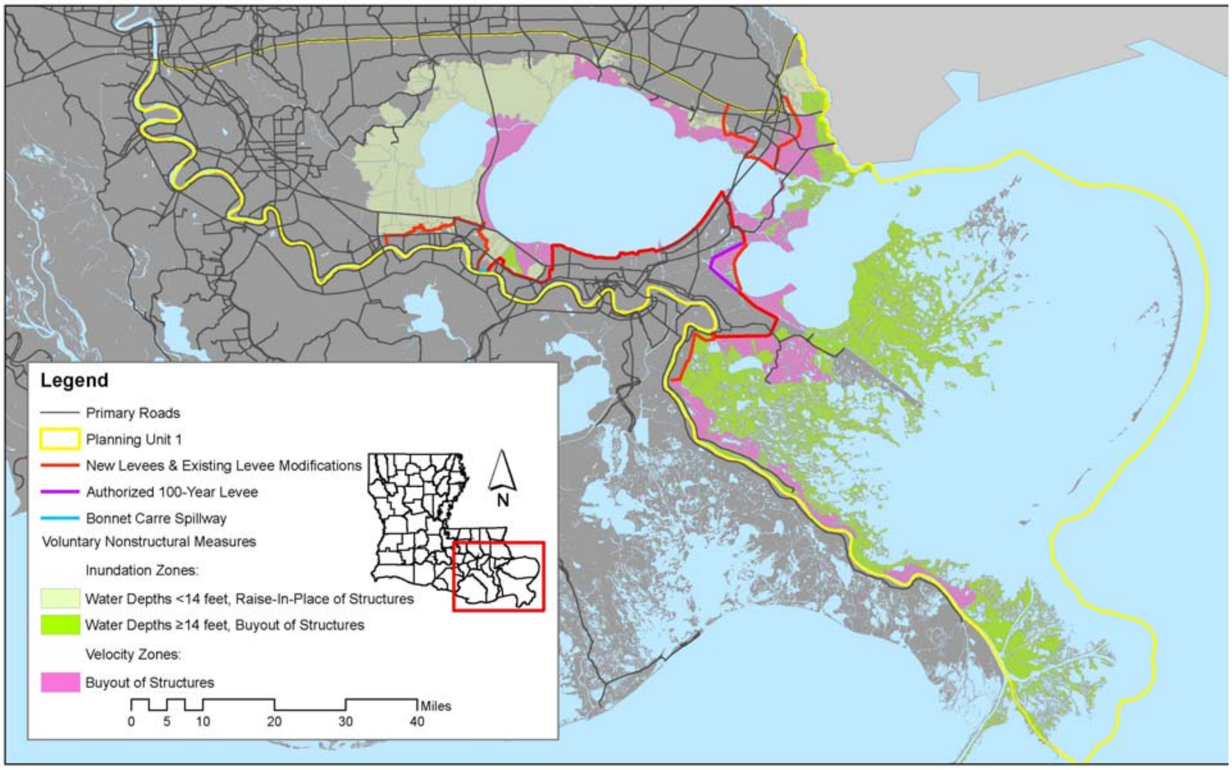


Figure 5-7. Planning Unit 1 – example comprehensive plan.



Alternatives in Planning Unit 2

The 33 alternatives in Planning Unit 2 are described in **Table 5-8**:

Table 5-8. Planning Unit 2 alternatives.

Category	Alternative	Alternative Description
No Action	PU2-0	No action (without project) alternative.
Coastal Restoration Only	PU2-R1, R2, and R3	Sustain coastal landscape through restoration including shoreline protection, marsh creation, and diversions. R1 proposes steady state diversions while R2 proposes pulsed diversions. R3 is as proposed in the State Master Plan.
Coastal Restoration and Nonstructural Measures	PU2-NS-100, -400, and -1000	Sustain coastal landscape through restoration. Implement comprehensive 100-year, 400-year or 1000-year nonstructural measures.
Coastal Restoration and Structural Measures	PU2-WBI-100-1	Sustain coastal landscape through restoration. Construct new sector gate on Bayou Barataria to reduce risk on the West Bank.
	PU2-WBI-400-1	Sustain coastal landscape through restoration. Construct new sector gate on Bayou Barataria to reduce risk on the West Bank. Raise West Bank and Vicinity and Larose to Golden Meadow levees to 400-year level of risk reduction.
	PU2-R-100-2	Sustain coastal landscape through restoration. Construct new sector gate on Bayou Barataria to reduce risk on the West Bank. Extend West Bank and Vicinity levees to Boutte and construct/raise Lafitte ring levees to 100-year level of risk reduction.
	PU2-R-400-2	Sustain coastal landscape through restoration. Construct new sector gate on Bayou Barataria to reduce risk on the West Bank. Extend West Bank and Vicinity levees to Boutte and raise those levees as well as Larose to Golden Meadow levees to 400-year level of risk reduction. Construct/raise Lafitte ring levees to 100-year level of risk reduction.
	PU2-R-100-3	Sustain coastal landscape through restoration. Construct new sector gate on Bayou Barataria to reduce risk on the West Bank. Extend West Bank and Vicinity levees to Boutte and construct/raise Lafitte and Des Allemands ring levees to 100-year level of risk reduction.
	PU2-R-400-3	Sustain coastal landscape through restoration. Construct new sector gate on Bayou Barataria to reduce risk on the West Bank. Extend West Bank and Vicinity levees to Boutte and raise those levees as well as Des Allemands and Larose to Golden Meadow levees to 400-year level of risk reduction. Construct/raise Lafitte ring levees to 100-year level of risk reduction.
	PU2-R-100-4	Sustain coastal landscape through restoration. Construct new sector gate on Bayou Barataria to reduce risk on the West Bank. Construct/raise Lafitte and Des Allemands ring levees to 100-year level of risk reduction and build new levees around Boutte and up the east side of Bayou Lafourche from Larose to Highway 90 at the 100-year level of risk reduction.

Category	Alternative	Alternative Description
	PU2-R-400-4	Sustain coastal landscape through restoration. Construct new sector gate on Bayou Barataria to reduce risk on the West Bank. Extend West Bank and Vicinity levees to Boutte; extend levees from Larose up Bayou Lafourche to Highway 90; and raise Des Allemands ring levees to 400-year level of risk reduction. Construct/raise Lafitte ring levees to 100-year level of risk reduction.
	PU2-R-1000-4	Sustain coastal landscape through restoration. Construct new sector gate on Bayou Barataria to reduce risk on the West Bank. Extend West Bank and Vicinity levees to Boutte; extend levees from Larose up Bayou Lafourche to Highway 90; and raise Des Allemands ring levees to 1000-year level of risk reduction. Construct/raise Lafitte ring levees to 100-year level of risk reduction.
	PU2-G-100-1	Sustain coastal landscape through restoration. Similar structural features as PU2-WBI-100-1 but with additional barrier-weir and levees along the GIWW to reduce risk to areas within the Barataria Basin. Also reduces risk to the Lafitte area.
	PU2-G-100-4	Sustain coastal landscape through restoration. Similar structural features as PU2-R-100-4 but with additional barrier-weir and levees along the GIWW to reduce risk to areas within the Barataria Basin. Also reduces risk to the Lafitte area.
	PU2-G-400-4	Sustain coastal landscape through restoration. Similar structural features as PU2-R-400-4 but with additional barrier-weir and levees along the GIWW to reduce risk to areas within the Barataria Basin. Also reduces risk to the Lafitte area.
	PU2-G-1000-4	Sustain coastal landscape through restoration. Similar structural features as PU2-R-1000-4 but with additional barrier-weir and levees along the GIWW to reduce risk to areas within the Barataria Basin. Also reduces risk to the Lafitte area.
Comprehensive (Coastal, Structural, and Nonstructural)	PU2-C-X-xxx-x	Structural/coastal alternatives are made comprehensive by adding complementary nonstructural measures to reduce residual risk in areas without structural risk reduction measures. Comprehensive alternatives are noted by a “C-“ in front of the structural/coastal alternative code.

Figure 5-8. Planning Unit 2 – example coastal restoration plan.

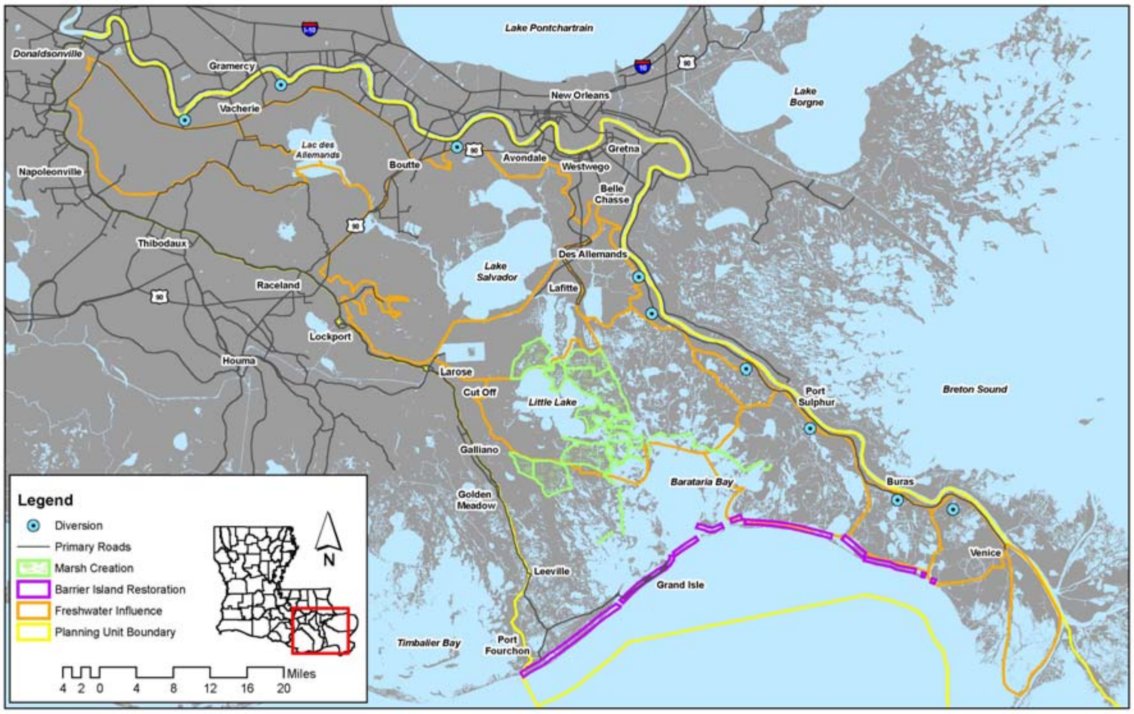
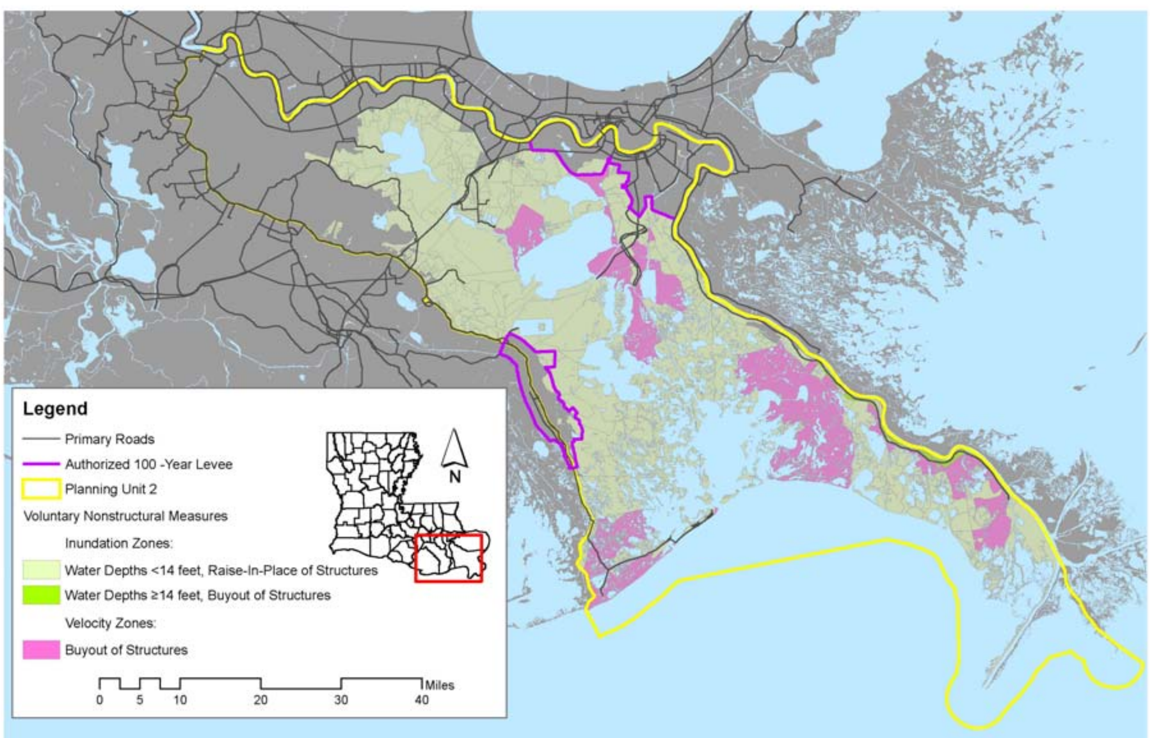
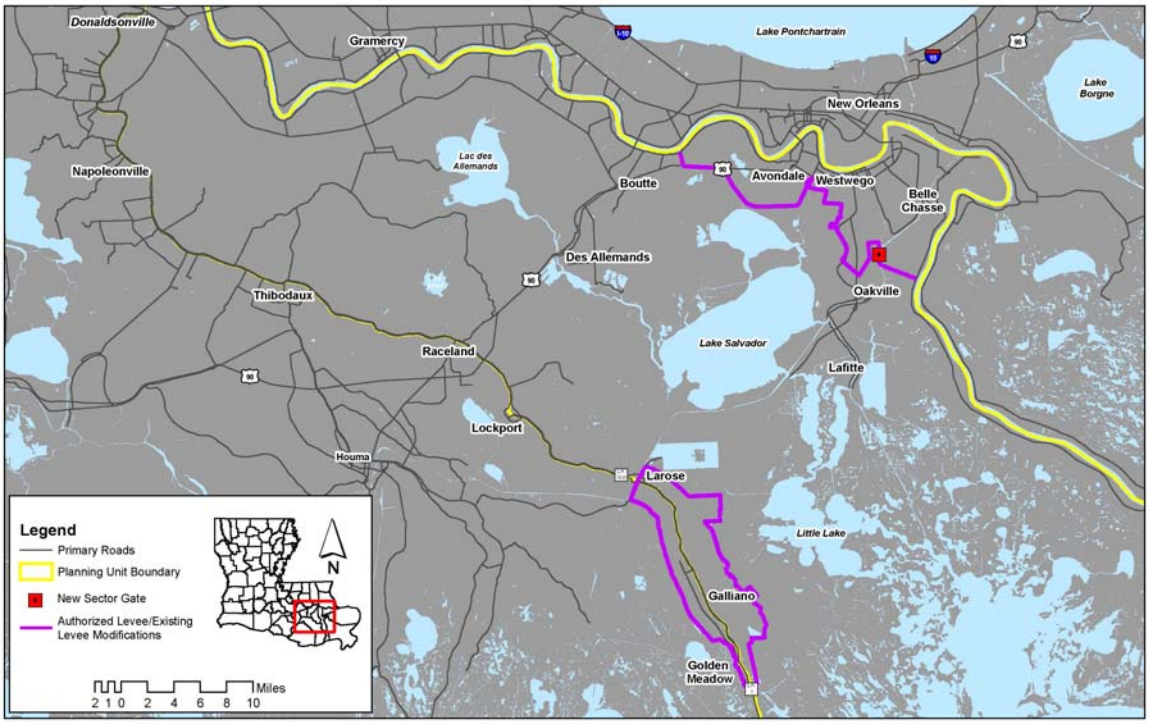


Figure 5-9. Planning Unit 2 – example nonstructural plan.

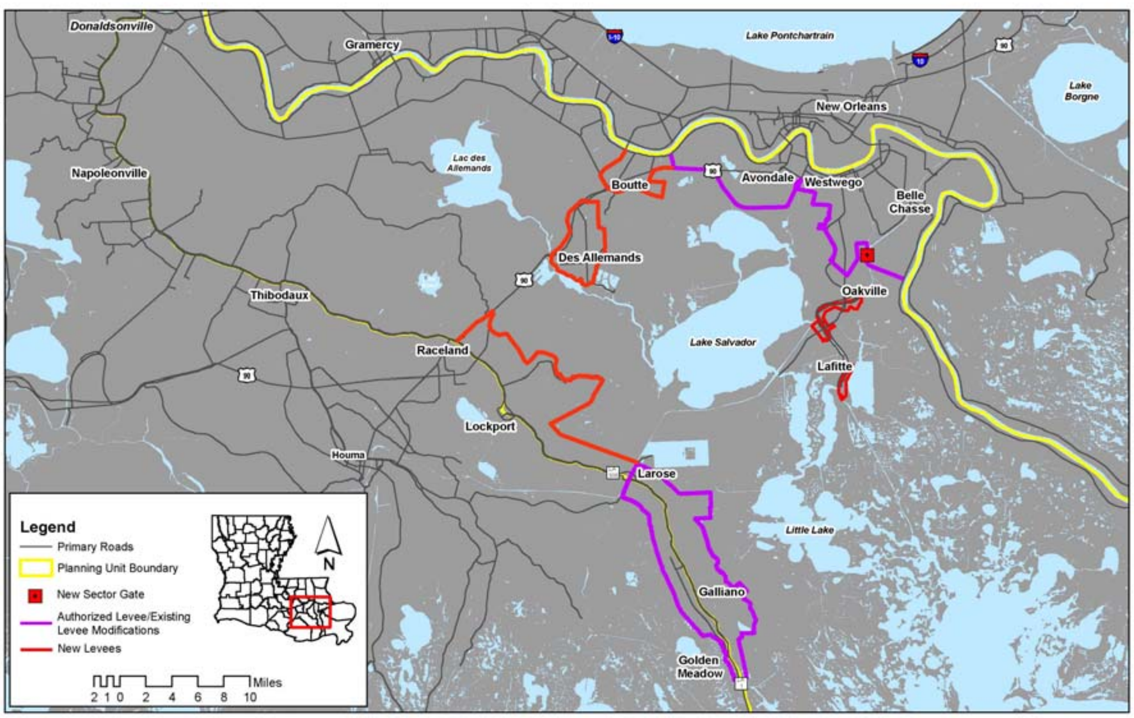


2877 **Figure 5-10. Planning Unit 2 – example West Bank interior alignment.**



2878

2879 **Figure 5-11. Planning Unit 2 – example ridge alignment.**



2880

Figure 5-12. Planning Unit 2 – example GIWW alignment.

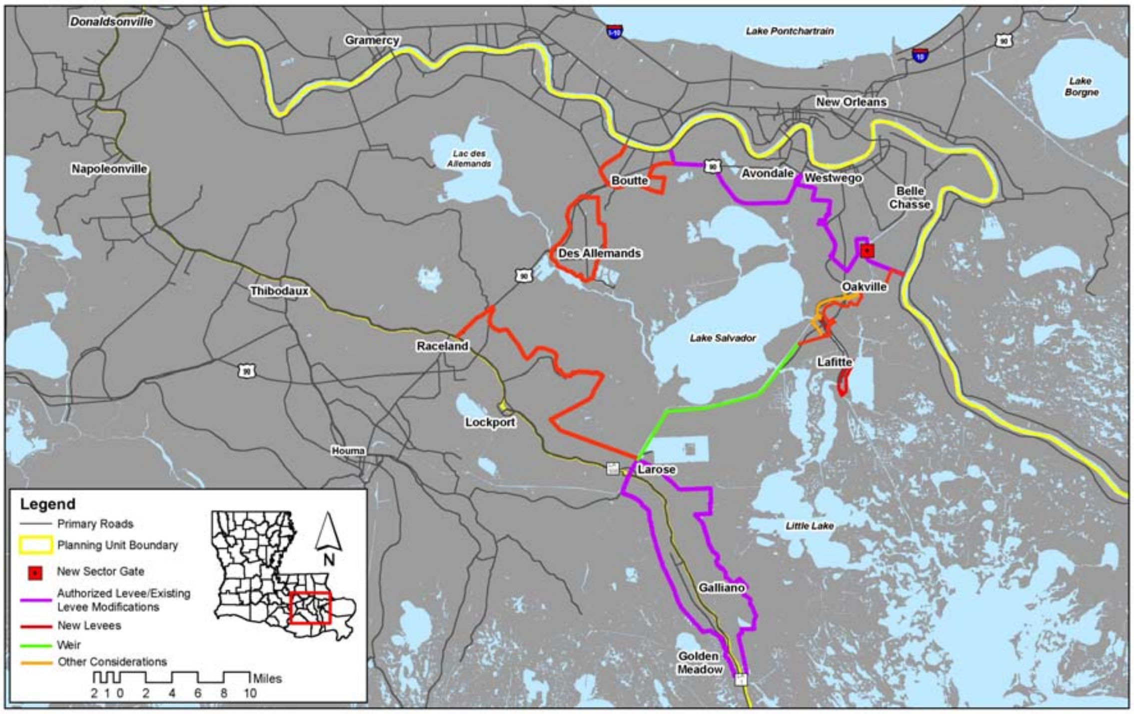
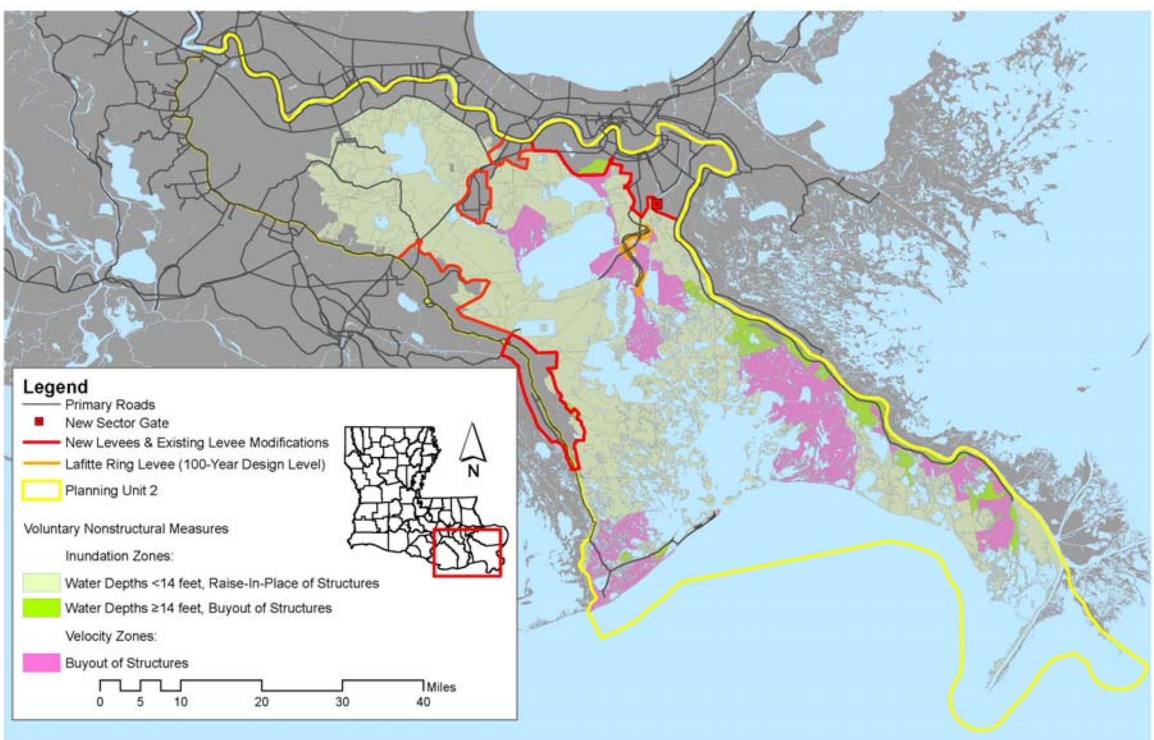


Figure 5-13. Planning Unit 2 – example comprehensive plan.



Alternatives in Planning Unit 3a

The 13 alternatives in Planning Unit 3a are described in **Table 5-9**:

Table 5-9. Planning Unit 3a alternatives.

Category	Alternative	Alternative Description
No Action	PU3a-0	No action (without project) alternative.
Coastal Restoration Only	PU3a-R1	Sustain coastal landscape through restoration including shoreline protection, marsh creation, and diversions from the Mississippi River.
Coastal Restoration and Nonstructural Measures	PU3a-NS-100, -400, and -1000	Sustain coastal landscape through restoration. Implement comprehensive 100-year, 400-year or 1000-year nonstructural measures.
Coastal Restoration and Structural Measures	PU3a-M-100-1	Sustain coastal landscape through restoration. Construct Morganza to the Gulf levee with extension tying into high ground west of Morgan City at 100-year design level.
	PU3a-M-100-2	Sustain coastal landscape through restoration. Construct Morganza to the Gulf levee with with tieback to high ground south of Thibodaux and ring levee around Morgan City at 100-year design level.
	PU3a-G-400-2	Sustain coastal landscape through restoration. Construct Morganza to the Gulf levee at the 100-year design level with a second levee along the GIWW with tieback to high ground south of Thibodaux and ring levee around Morgan City providing a 400-year level of risk reduction for Houma and Morgan City.
	PU3a-G-1000-2	Sustain coastal landscape through restoration. Construct Morganza to the Gulf levee at the 100-year design level and a second levee along the GIWW with tieback to high ground south of Thibodaux and ring levee around Morgan City providing a 1000-year level of risk reduction for Houma and Morgan City.
Comprehensive (Coastal, Structural, and Nonstructural)	PU3a-C-X-xxx-x	Structural/coastal alternatives are made comprehensive by adding complementary nonstructural measures to reduce residual risk in areas without structural risk reduction measures. Comprehensive alternatives are noted by a “C-“ in front of the structural/coastal alternative code.

Note: Although the Water Resource Development Act 2007 recently authorized the Morganza to the Gulf project, it is not included in the without-project conditions since it was not authorized at the time the analysis was conducted.

Figure 5-14. Planning Unit 3a – example coastal restoration plan.

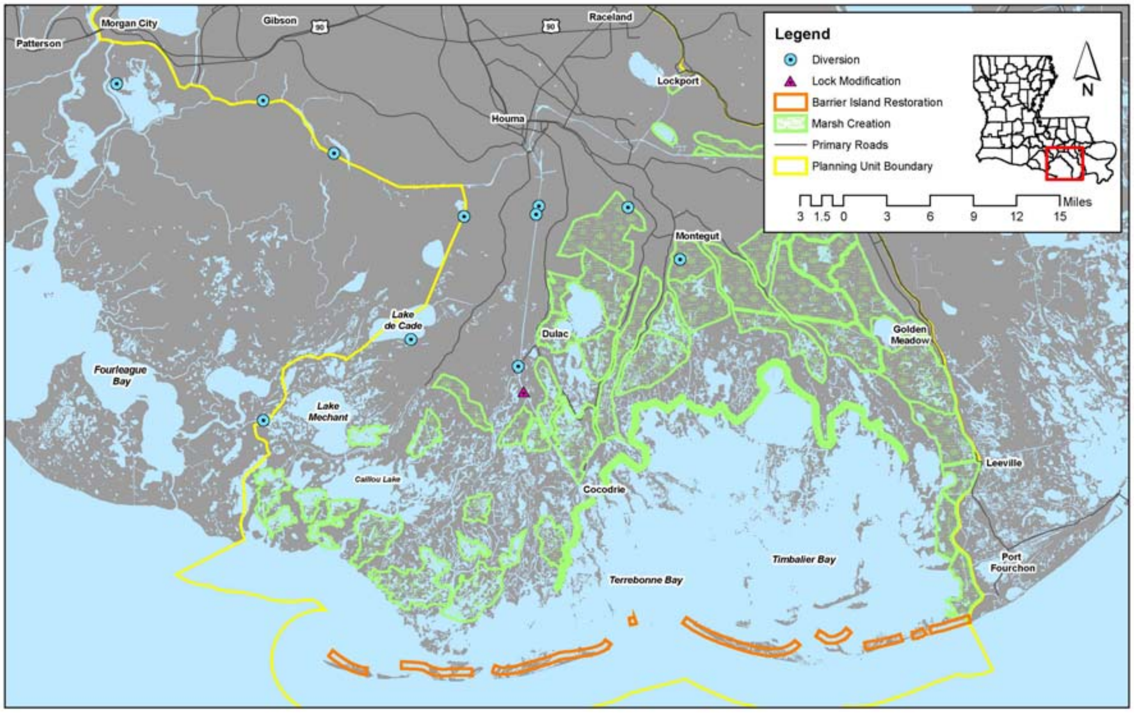


Figure 5-15. Planning Unit 3a – example nonstructural plan.

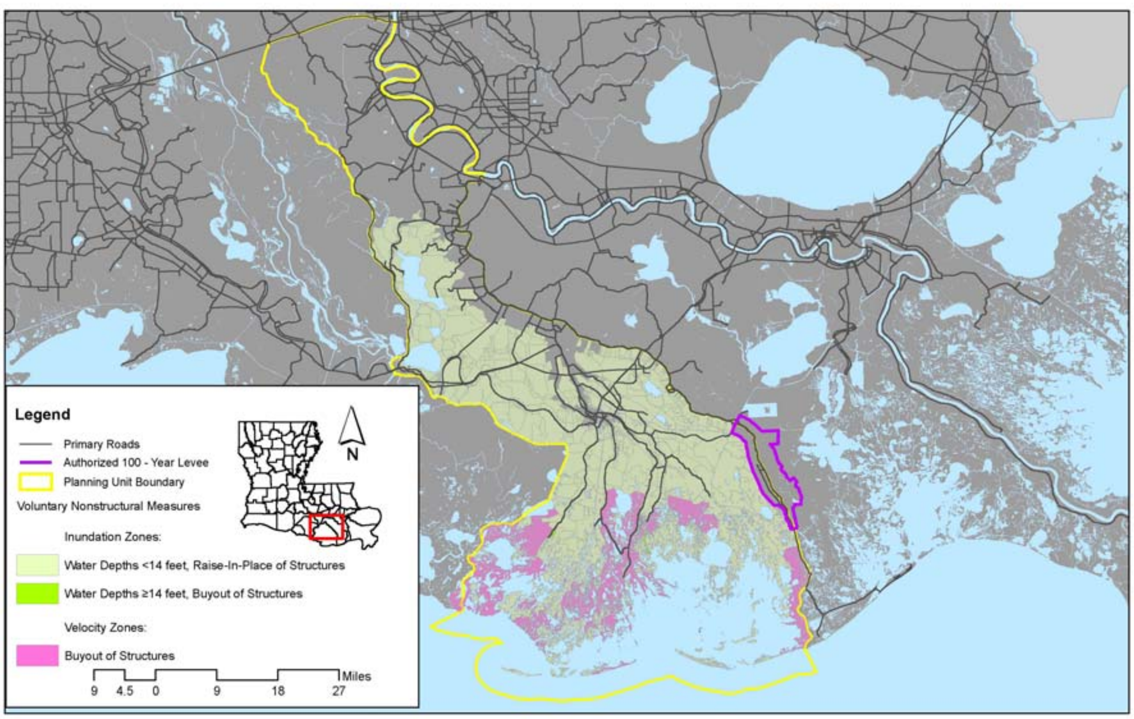


Figure 5-16. Planning Unit 3a – example Morganza alignment.

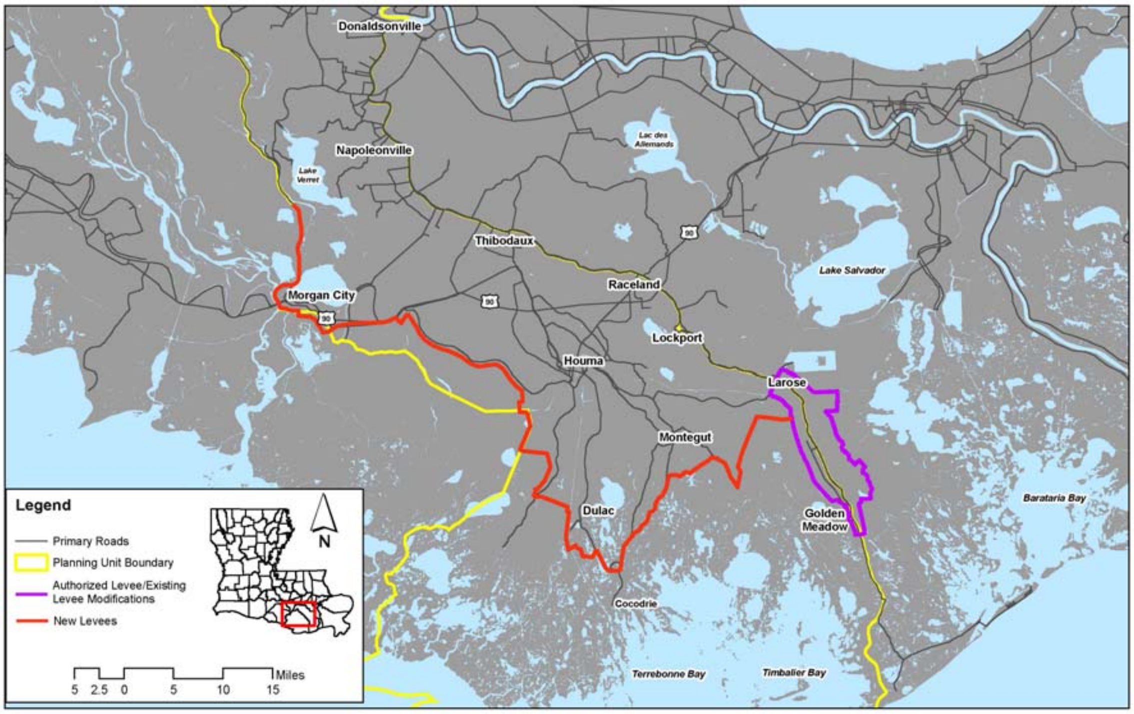


Figure 5-17. Planning Unit 3a – example Morganza/ring levee alignment.

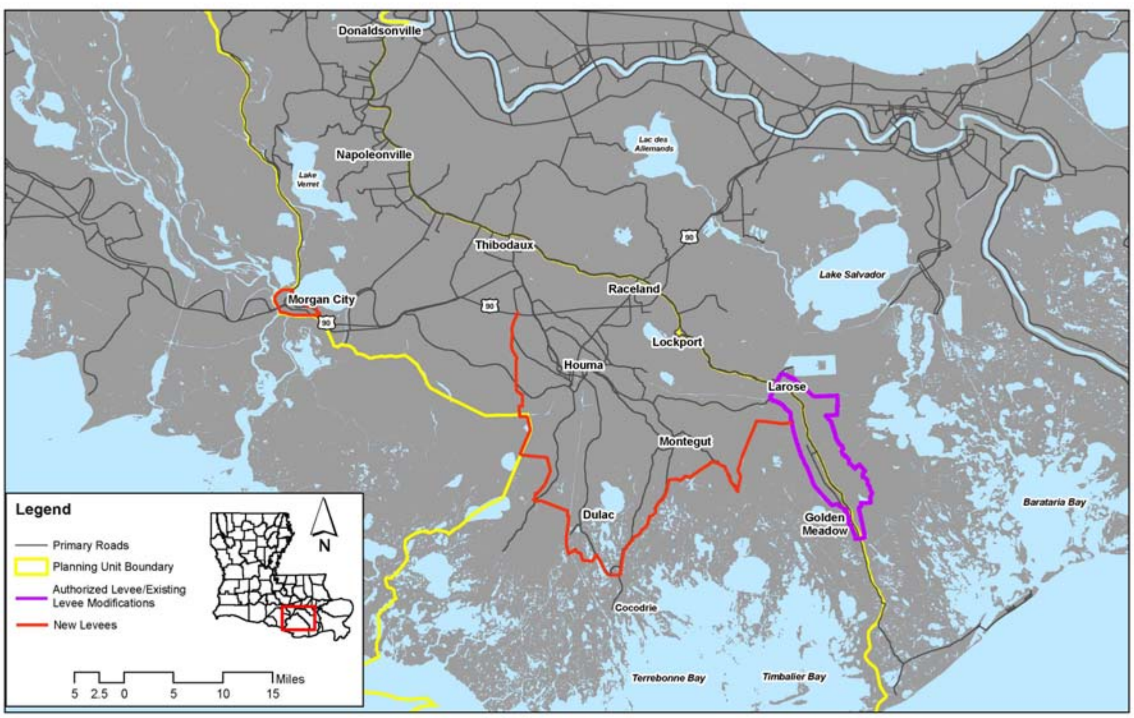


Figure 5-18. Planning Unit 3a – example GIWW/Morganza/ring levee alignment.

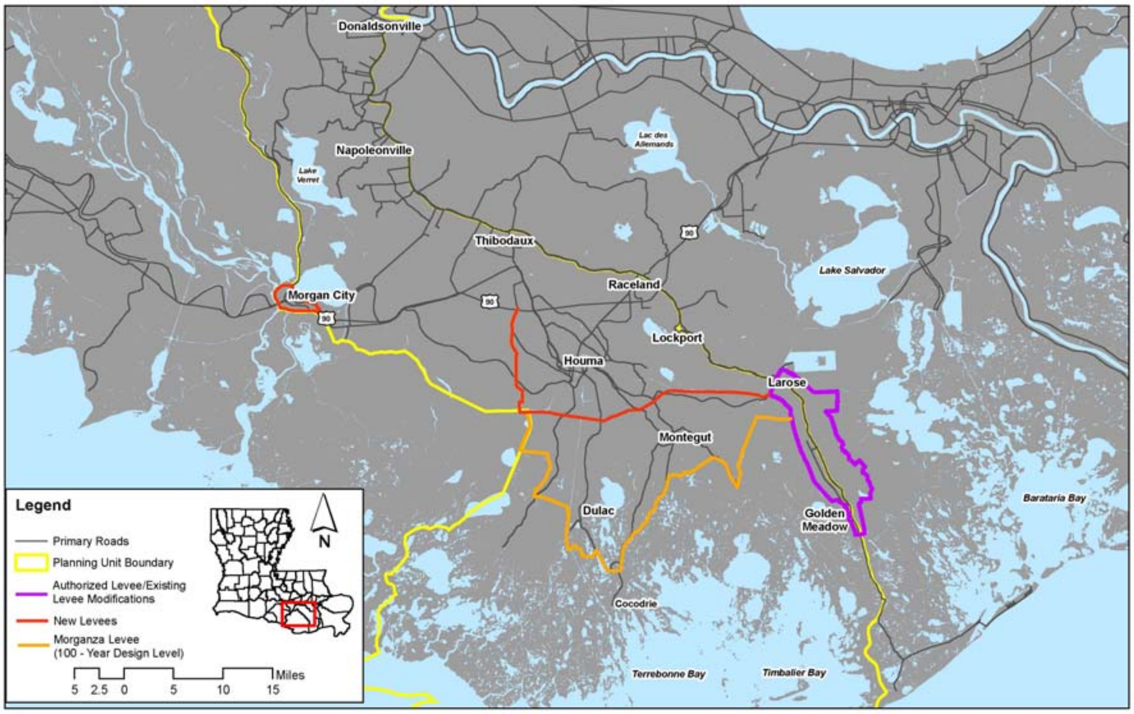
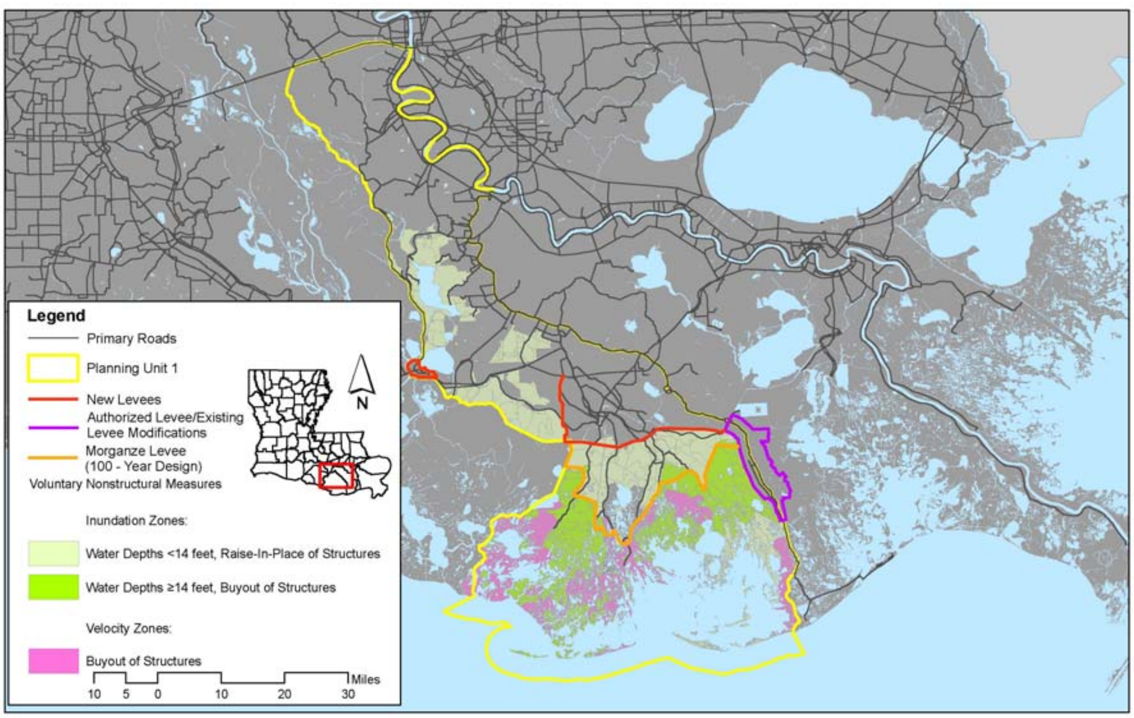


Figure 5-19. Planning Unit 3a – example comprehensive plan.



Alternatives in Planning Unit 3b

The 17 alternatives in Planning Unit 3b are described in **Table 5-10**:

Table 5-10. Planning Unit 3b alternatives.

Category	Alternative	Alternative Description
No Action	PU3b-0	No action (without project) alternative.
Coastal Restoration Only	PU3b-R1	Sustain coastal landscape through restoration including shoreline protection, marsh creation, etc.
Coastal Restoration and Nonstructural Measures	PU3b-NS-100, -400, and -1000	Sustain coastal landscape through restoration. Implement comprehensive 100-year, 400-year or 1000-year nonstructural measures.
Coastal Restoration and Structural Measures	PU3b-G-100-1	Sustain coastal landscape through restoration. Raise ring levee around Patterson/Berwick to 100-year design level and construct levee along the GIWW west to the boundary of Planning Unit 4 at the 100-year design level.
	PU3b-F-100-1	Sustain coastal landscape through restoration. Raise ring levee around Patterson/Berwick to 100-year design level and construct levee along the edge of development north of the GIWW to high ground west of Abbeville at the 100-year design level.
	PU3b-F-400-1	Sustain coastal landscape through restoration. Raise ring levee around Patterson/Berwick to 400-year design level and construct levee along the edge of development north of the GIWW to high ground west of Abbeville at the 400-year design level.
	PU3b-F-1000-1	Sustain coastal landscape through restoration. Raise ring levee around Patterson/Berwick to 1000-year design level and construct levee along the edge of development north of the GIWW to high ground west of Abbeville at the 1000-year design level.
	PU3b-RL-100-1	Sustain coastal landscape through restoration. Raise ring levee around Patterson/Berwick to 100-year design level and construct ring levees around Franklin/Baldwin, New Iberia, Erath, Delcambre, and Abbeville at the 100-year design level.
	PU3b-RL-400-1	Sustain coastal landscape through restoration. Raise ring levee around Patterson/Berwick to 400-year design level and construct ring levees around Franklin/Baldwin, New Iberia, Erath, Delcambre, and Abbeville at the 400-year design level.
Comprehensive (Coastal, Structural, and Nonstructural)	PU3b-C-X-xxx-x	Structural/coastal alternatives are made comprehensive by adding complementary nonstructural measures to reduce residual risk in areas without structural risk reduction measures. Comprehensive alternatives are noted by a “C-“ in front of the structural/coastal alternative code.

Figure 5-20. Planning Unit 3b – example coastal restoration plan.

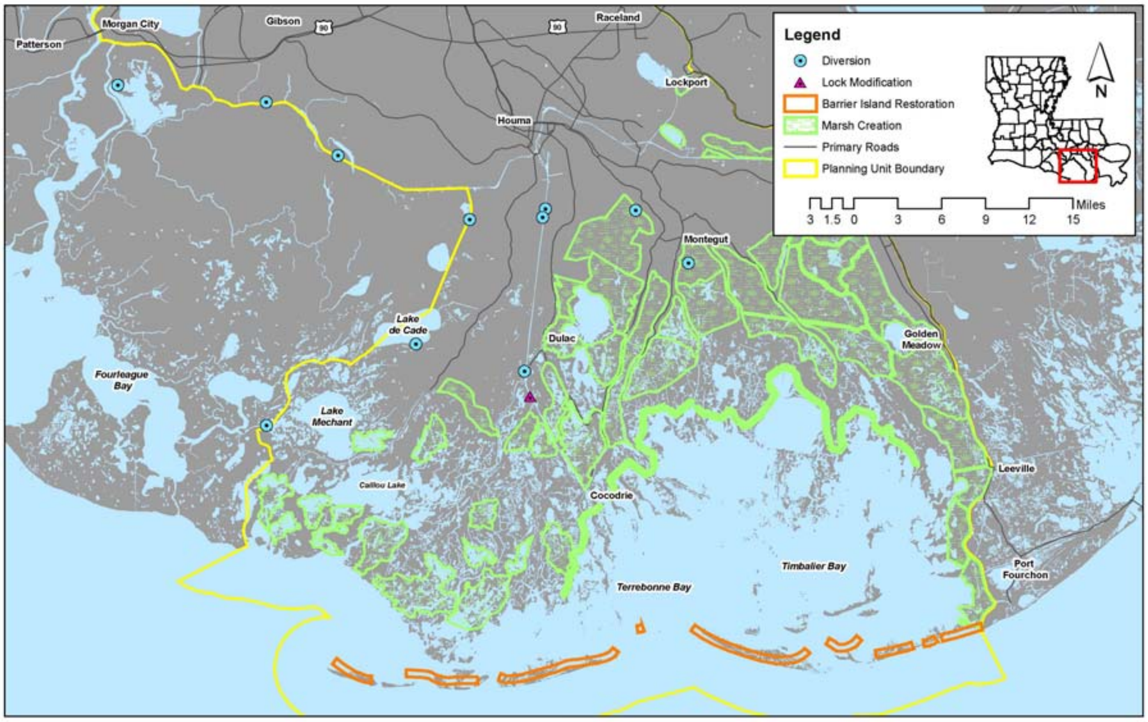


Figure 5-21. Planning Unit 3b – example nonstructural plan.

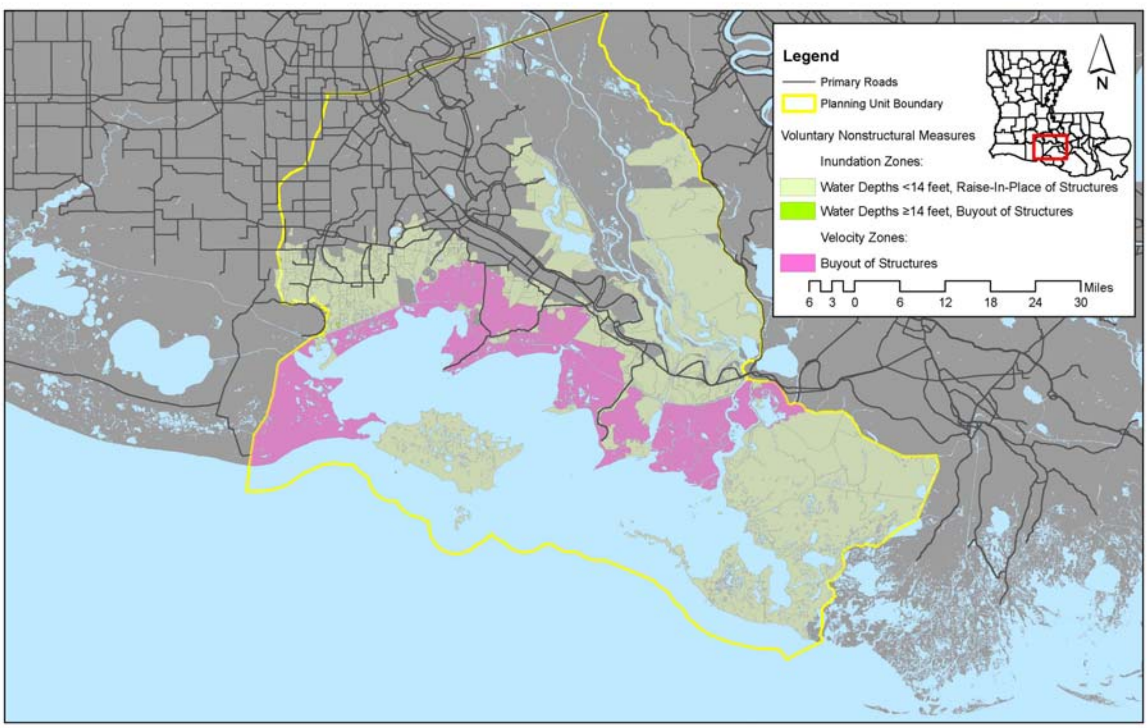


Figure 5-22. Planning Unit 3b – example GIWW alignment.

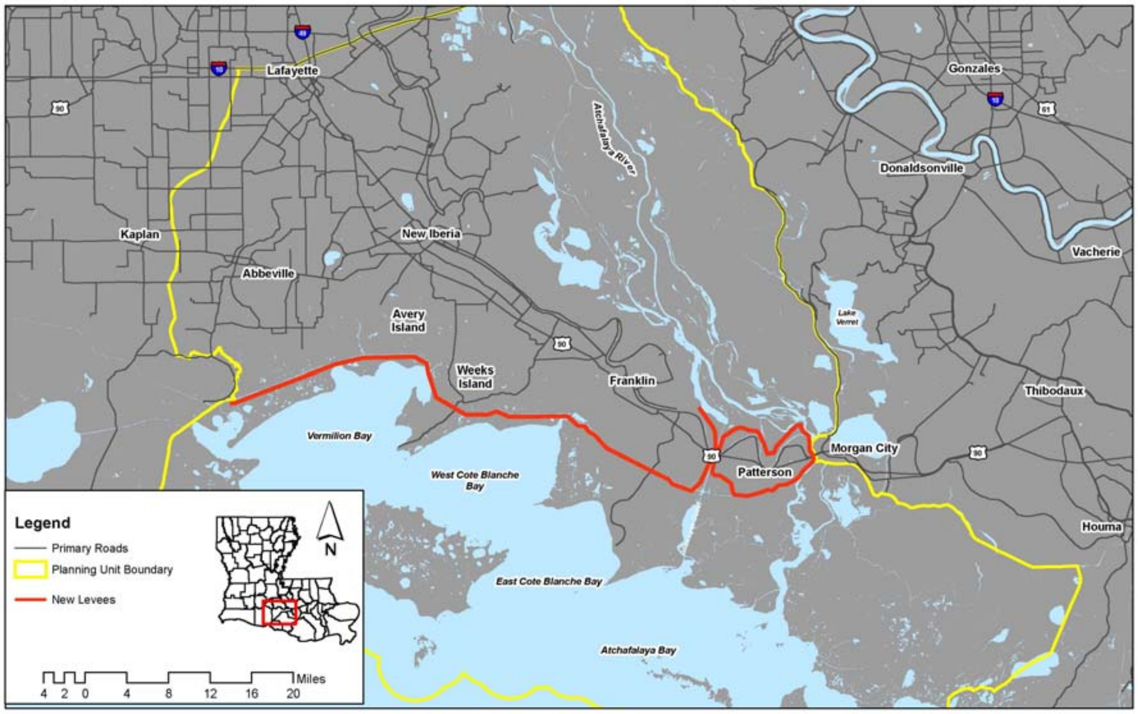


Figure 5-23. Planning Unit 3b – example Franklin to Abbeville alignment.

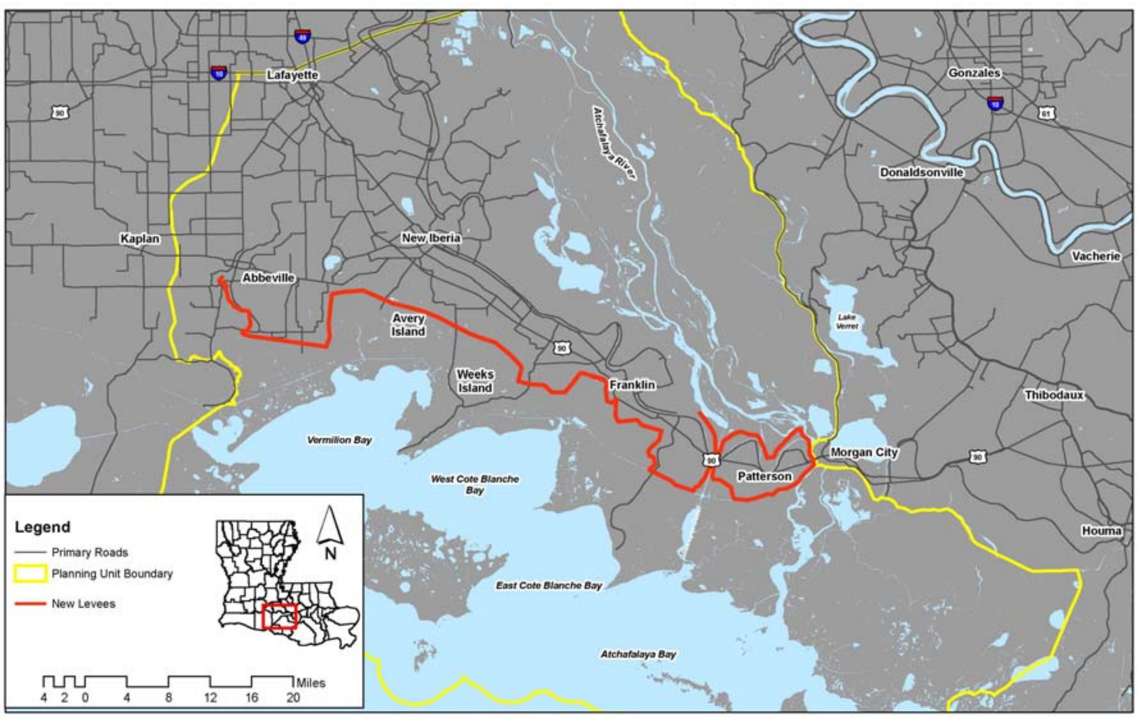


Figure 5-24. Planning Unit 3b – example ring levee alignment.

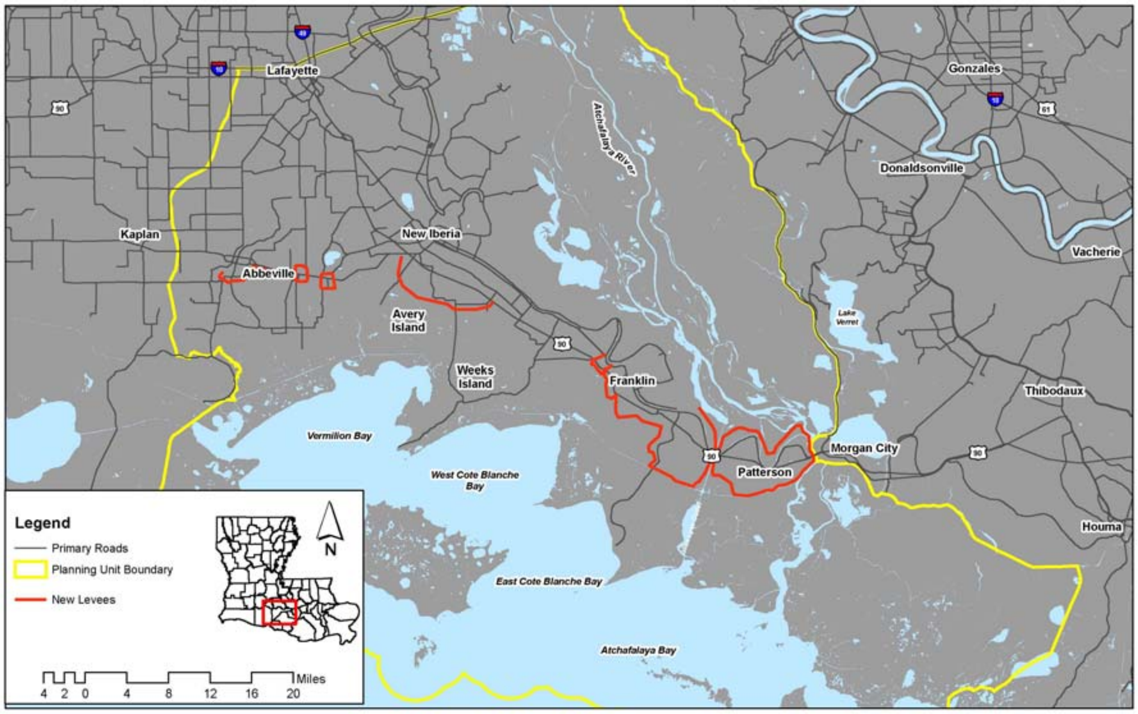
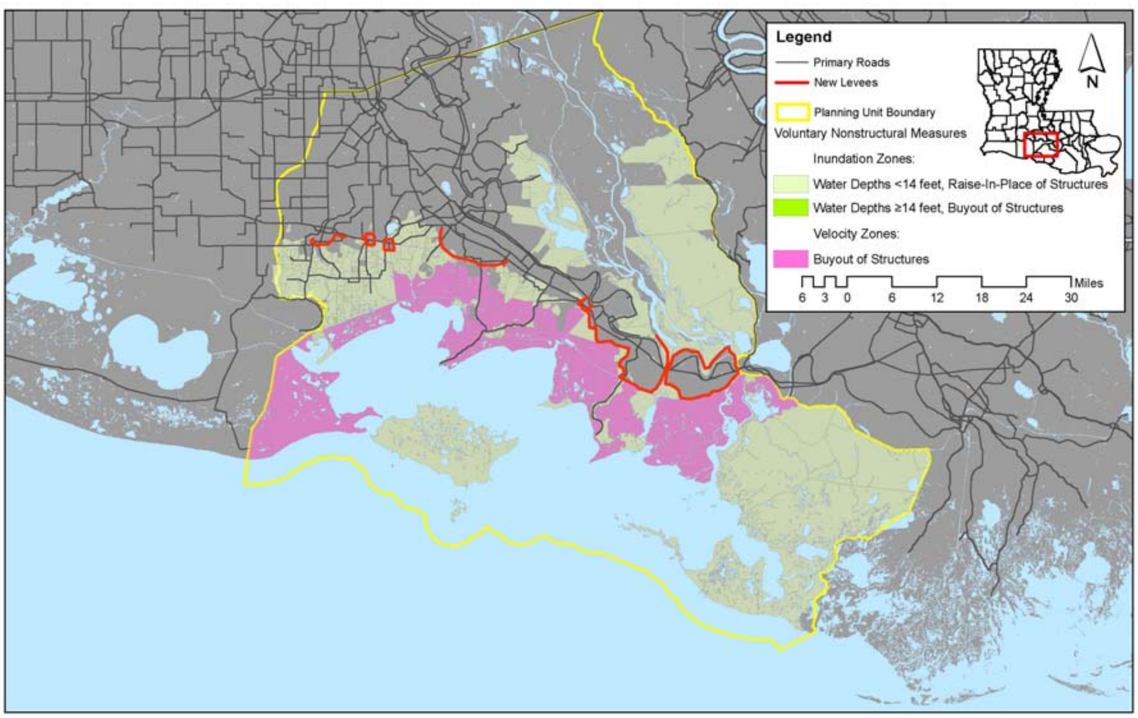


Figure 5-25. Planning Unit 3b – example comprehensive plan.



Alternatives in Planning Unit 4

The 19 alternatives in Planning Unit 4 are described in **Table 5-11**:

Table 5-11. Planning Unit 4 alternatives.

Category	Alternative	Alternative Description
No Action	PU4-0	No action (without project) alternative.
Coastal Restoration Only	PU4-R1	Sustain coastal landscape through restoration including shoreline protection, marsh creation, etc.
Coastal Restoration and Nonstructural Measures	PU4-NS-100, -400, and -1000	Sustain coastal landscape through restoration. Implement comprehensive 100-year, 400-year or 1000-year nonstructural measures.
Coastal Restoration and Structural Measures	PU4-G-100-1	Sustain coastal landscape through restoration. Construct a continuous levee (with gates) along the GIWW plus a ring levee to the west of the Calcasieu River and a series of levees within Lake Charles to separate the river from the land at the 100-year design level. Alignment joins with similar alignment in Planning Unit 3b.
	PU4-G-100-2	Sustain coastal landscape through restoration. Construct a continuous levee (with gates) along the GIWW plus a ring levee to the west of the Calcasieu River and a series of levees within Lake Charles to separate the river from the land at the 100-year design level. Alignment ties to high ground to the west of the Vermilion River so this alternative can be evaluated as "stand alone" from alternatives in Planning Unit 3b.
	PU4-G-400-3	Sustain coastal landscape through restoration. Construct a continuous 12-foot levee (with gates) along the GIWW plus a ring levee to the west of the Calcasieu River and a series of levees within Lake Charles to separate the river from the land. May include small ring levees around parts of Lake Charles, Gueydan, and Kaplan to provide 400-year level of risk reduction. Alignment ties to high ground to the west of the Vermilion River so this alternative can be evaluated as "stand alone" from alternatives in Planning Unit 3b.
	PU4-G-1000-3	Sustain coastal landscape through restoration. Construct a 12-foot continuous levee (with gates) along the GIWW plus a ring levee to the west of the Calcasieu River and a series of levees within Lake Charles to separate the river from the land. May include small ring levees around parts of Lake Charles, Gueydan, and Kaplan to provide 400-year level of risk reduction. Alignment ties to high ground to the west of the Vermilion River so this alternative can be evaluated as "stand alone" from alternatives in Planning Unit 3b.
	PU4-RL-100-1	Sustain coastal landscape through restoration. Construct ring levees to the east and west of Lake Charles; construct a series of levees within Lake Charles to separate the river from the land; and construct ring levees around Kaplan and Gueydan to the 100-year design level.

Category	Alternative	Alternative Description
	PU4-RL-400-1	Sustain coastal landscape through restoration. Construct ring levees to the east and west of Lake Charles; construct a series of levees within Lake Charles to separate the river from the land; and construct ring levees around Kaplan and Gueydan to the 400-year design level.
	PU4-RL-1000-1	Sustain coastal landscape through restoration. Construct ring levees to the east and west of Lake Charles; construct a series of levees within Lake Charles to separate the river from the land; and construct ring levees around Kaplan and Gueydan to 100-year design level.
Comprehensive (Coastal, Structural, and Nonstructural)	PU4-C-X-xxx-x	Structural/coastal alternatives are made comprehensive by adding complementary nonstructural measures to reduce residual risk in areas without structural risk reduction measures. Comprehensive alternatives are noted by a “C-“ in front of the structural/coastal alternative code.

Figure 5-26. Planning Unit 4 – example coastal restoration plan.

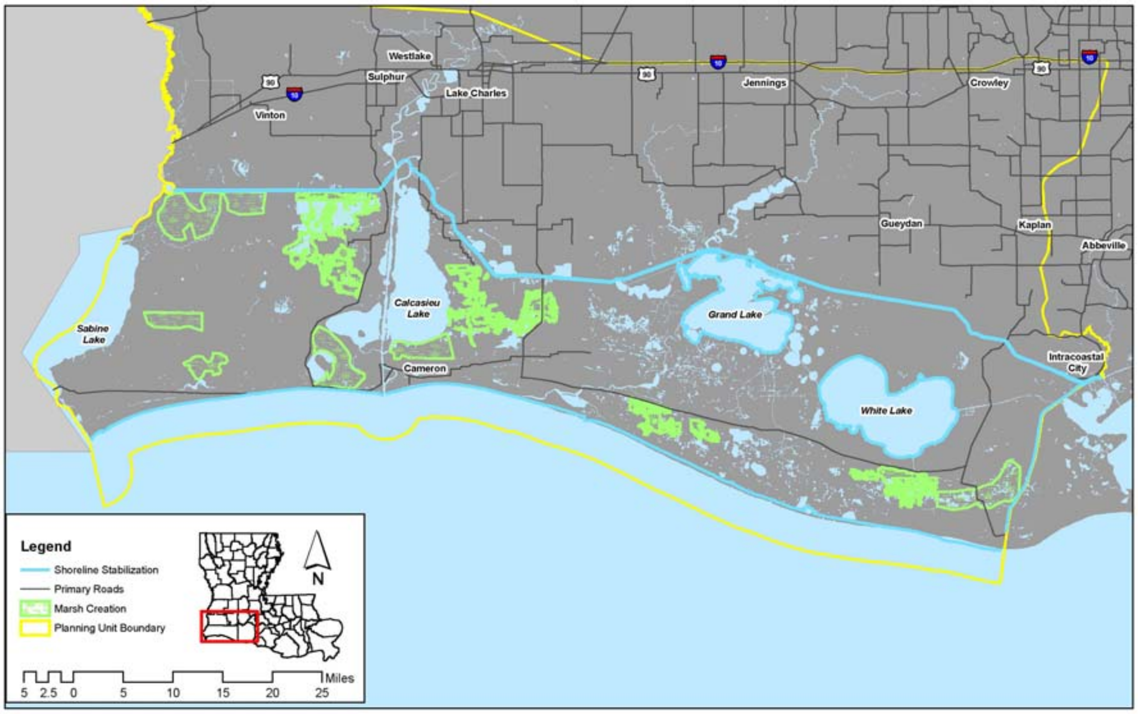


Figure 5-27. Planning Unit 4 – example nonstructural plan.

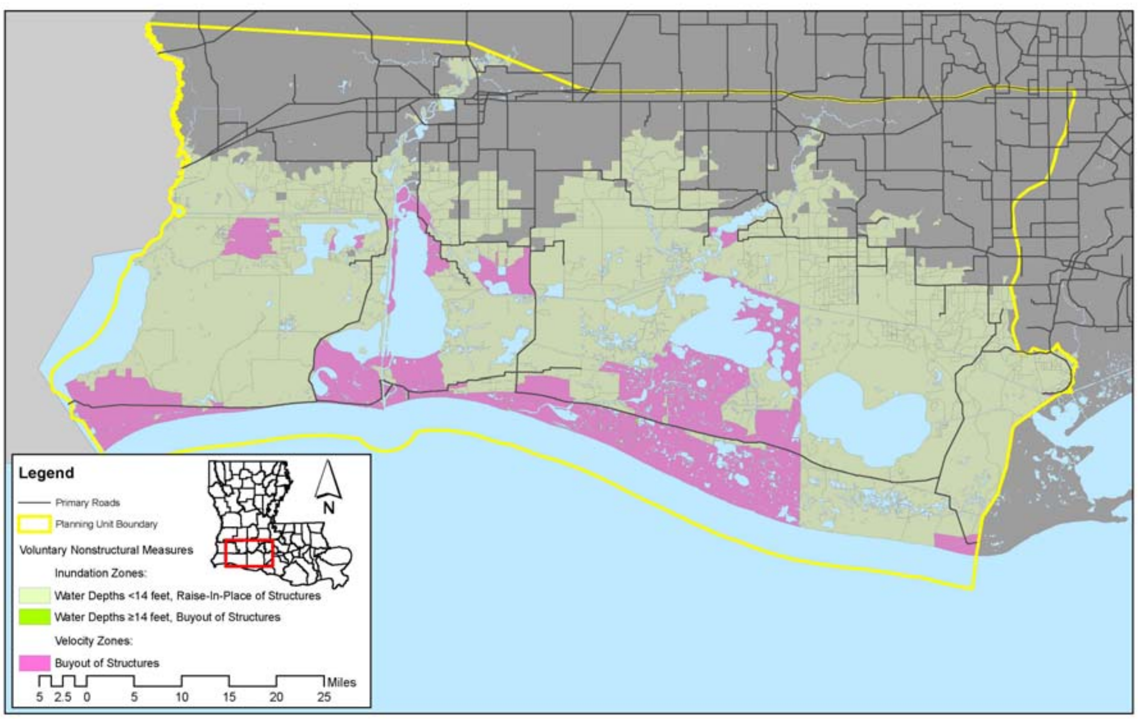


Figure 5-28. Planning Unit 4 – example GIWW alignment.

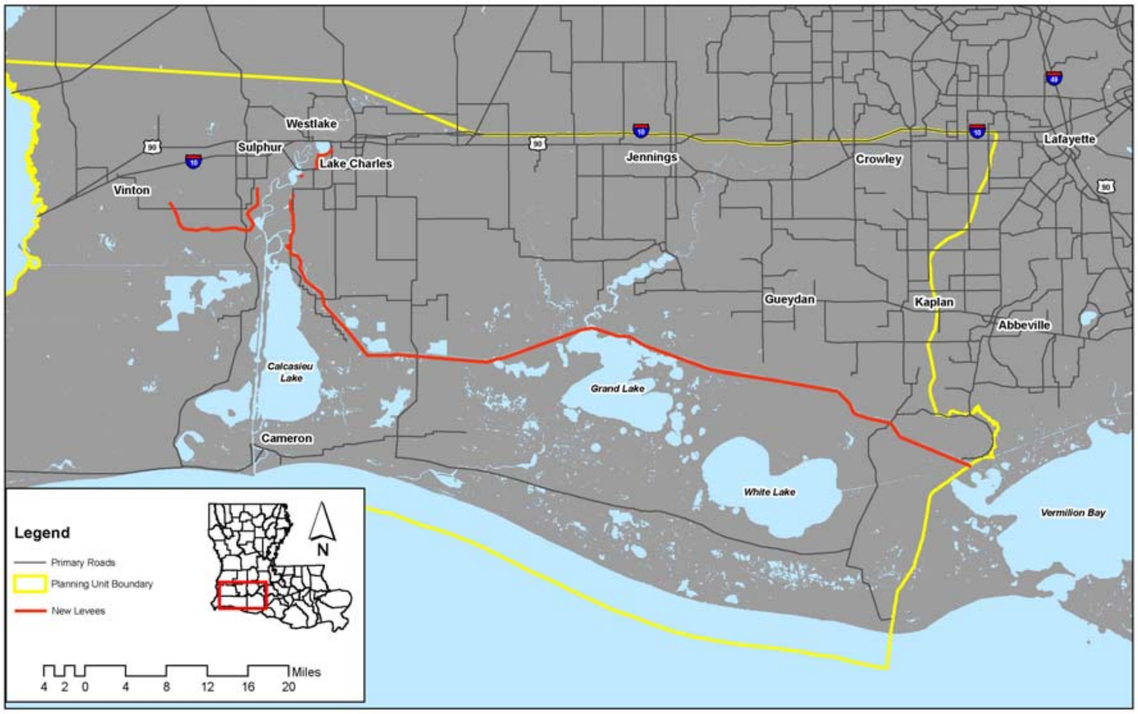


Figure 5-29. Planning Unit 4 – example GIWW alignments 2 and 3 (12-ft levee).

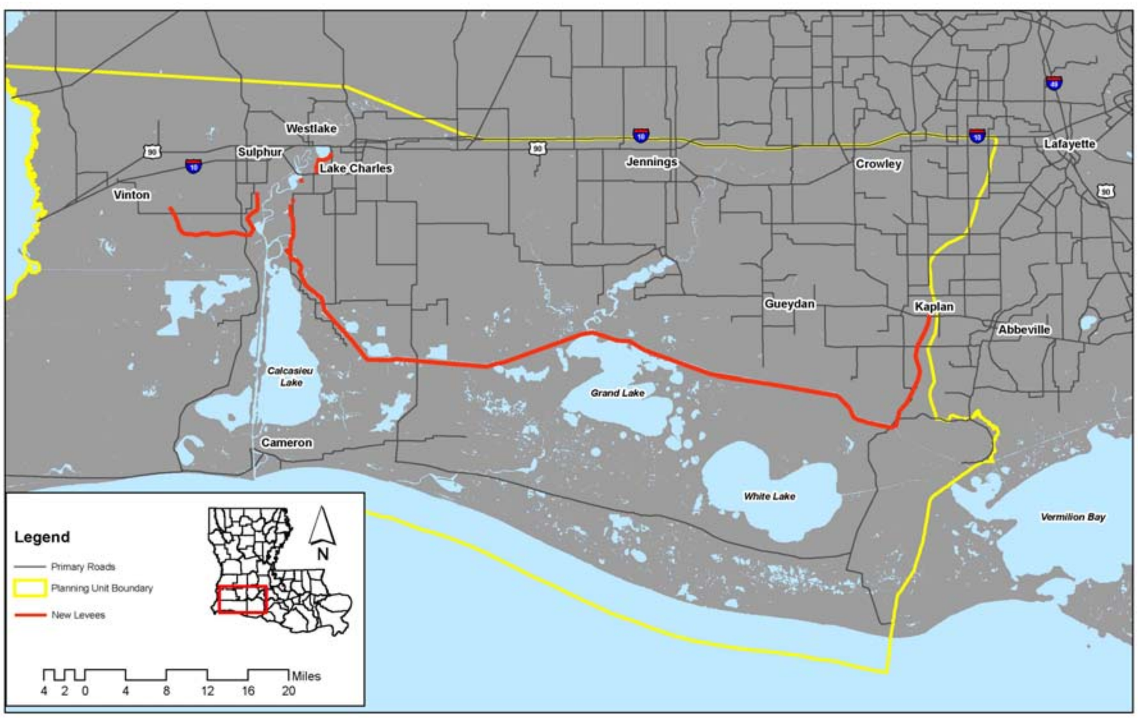


Figure 5-30. Planning Unit 4 – example ring levee alignment.

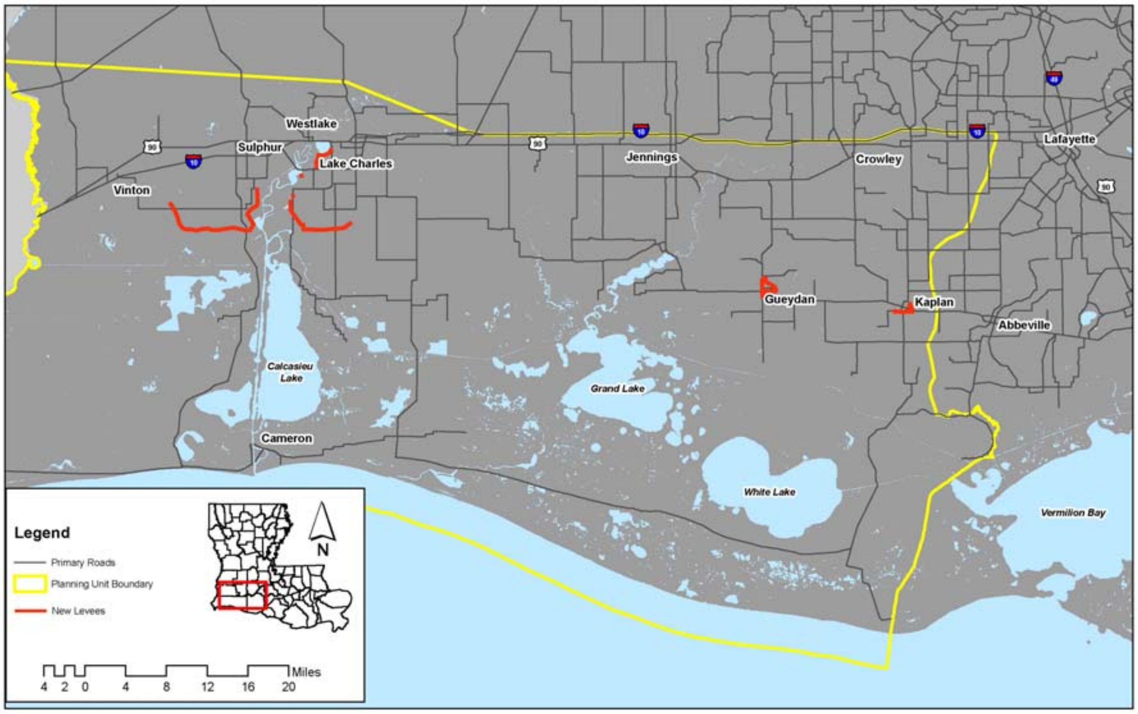


Figure 5-31. Planning Unit 4 – example comprehensive plan.

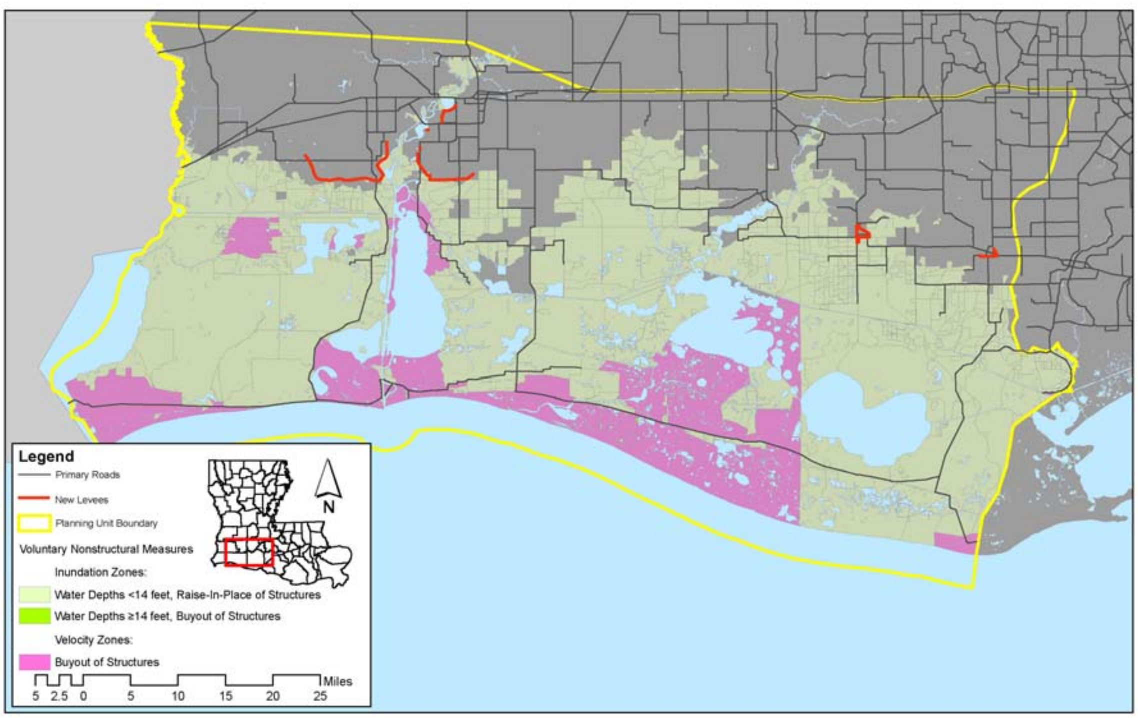


Table 5-12. Summary of LACPR alternatives evaluated.

Category	Planning Unit 1	Planning Unit 2	Planning Unit 3a	Planning Unit 3b	Planning Unit 4
No Action	PU1-0	PU2-0	PU3a-0	PU3b-0	PU4-0
Coastal Only	PU1-R1, R2, and R3	PU2- R1, R2, and R3	PU3a-R1	PU3b-R1	PU4-R1
Coastal* and Nonstructural	PU1-NS-100, 400, and 1000	PU2-NS-100, 400, and 1000	PU3a-NS-100, 400, and 1000	PU3b-NS-100, 400, and 1000	PU4-NS-100, 400, and 1000
Coastal* and Structural	PU1-LP-a-100-1	PU2-WBI-100-1	PU3a-M-100-1	PU3b-G-100-1	PU4-G-100-1
	PU1-LP-a-100-2	PU2-WBI-400-1	PU3a-M-100-2	PU3b-F-100-1	PU4-G-100-2
	PU1-LP-a-100-3	PU2-R-100-2	PU3a-G-400-2	PU3b-F-400-1	PU4-G-400-3
	PU1-LP-b-400-1	PU2-R-400-2	PU3a-G-1000-2	PU3b-F-1000-1	PU4-G-1000-3
	PU1-LP-b-400-3	PU2-R-100-3		PU3b-RL-100-1	PU4-RL-100-1
	PU1-LP-b-1000-1	PU2-R-400-3		PU3b-RL-400-1	PU4-RL-400-1
	PU1-LP-b-1000-2	PU2-R-100-4			PU4-RL-1000-1
	PU1-HL-a-100-3	PU2-R-400-4			
	PU1-HL-a-100-2	PU2-R-1000-4			
	PU1-HL-b-400-3	PU2-G-100-1			
		PU2-G-100-4			
		PU2-G-400-4			
		PU2-G-1000-4			
Comprehensive Plans (Coastal,* Structural, and Nonstructural)	PU1-C-LP-a-100-1	PU2-C-WBI-100-1	PU3a-C-M-100-1	PU3b-C-G-100-1	PU4-C-G-100-1
	PU1-C-LP-a-100-2	PU2-C-WBI-400-1	PU3a-C-M-100-2	PU3b-C-F-100-1	PU4-C-G-100-2
	PU1-C-LP-a-100-3	PU2-C-R-100-2	PU3a-C-G-400-2	PU3b-C-F-400-1	PU4-C-G-400-3
	PU1-C-LP-b-400-1	PU2-C-R-400-2	PU3a-C-G-1000-2	PU3b-C-F-1000-1	PU4-C-G-1000-3
	PU1-C-LP-b-400-3	PU2-C-R-100-3		PU3b-C-RL-100-1	PU4-C-RL-100-1
	PU1-C-LP-b-1000-1	PU2-C-R-400-3		PU3b-C-RL-400-1	PU4-C-RL-400-1
	PU1-C-LP-b-1000-2	PU2-C-R-100-4			PU4-C-RL-1000-1
	PU1-C-HL-a-100-3	PU2-C-R-400-4			
	PU1-C-HL-a-100-2	PU2-C-R-1000-4			
	PU1-C-HL-b-400-3	PU2-C-G-100-1			
		PU2-C-G-100-4			
		PU2-C-G-400-4			
		PU2-C-G-1000-4			

*In Planning Units 1 and 2, coastal restoration alternative R2 is used as the representative landscape for combining with the structural, nonstructural, and comprehensive alternatives. In Planning Units 3a, 3b, and 4, R1 is used as the representative landscape.

Section 6. Evaluation of Alternatives

In view of the costs involved, decision makers and the public must ask an important question: *What is the acceptable level of risk?* The team evaluated a range of alternatives to assess economic, social, ecological, and cultural benefits and impacts, as well as construction, operations, maintenance, and repair costs. The alternatives help show differences between various inundation frequencies (100-year, 400-year, and 1000-year) and what they mean in terms of levee heights, costs, and residual damages. The following sections describe the methodology and performance metrics used to evaluate the alternatives listed in the previous section. The metric results are located in the *Evaluation Results Appendix*.

Hydromodeling Analysis: The Foundation for Metrics

State-of-the-art hydromodeling was used to simulate conditions for a range of storm events (10-year to 2000-year) for all of the alternative plans. The hydromodeling process was applied to each alternative plan to determine the behavior of the surge and waves outside the levee system during a storm event; the interaction between structural measures, coastal features, and incoming surge and waves during a storm event; and the likelihood of flooding that could occur inside the levee system from overtopping and rainfall during a storm event. More details on the hydromodeling analysis performed for LACPR can be found in the *Hydraulics and Hydrology Appendix*.

Variables in the Hydromodeling Analysis

The hydromodeling process analyzed many variables for each alternative and was used to generate outputs, which support the evaluation and comparison of the alternative plans across a range of metrics. Static inputs to the hydromodeling process included ground elevations, bathymetry, and pumping/storage capacity inside the levee system. Variable inputs that were analyzed included:

- Storm intensity, path, and frequency;
- Relative sea level rise;
- Base and future degraded conditions of the coastal landscape outside the levee system;
- Potential improvements to the coastal landscape outside the levee system;
- Storm surge height/duration;
- Wave characteristics;
- Levee system height and location; and
- Rainfall volume/duration.

For the interior flood modeling approach, the use of stage-storage routing relationships to estimate flood levels behind the levees due to overtopping and rainfall was adopted to parallel the IPET risk and reliability approach.

The Step-Wise Hydromodeling Analysis

The step-wise procedure used for the LACPR hydromodeling analysis is outlined in "Elevations for Design of Hurricane Protection Levees and Structures," prepared by the USACE New

Orleans District dated October 9, 2007. The report describes five steps used in the design procedure. Each step is intended to ensure that individual designers follow procedures that will provide consistency in design when different designers work on various reaches of a large project. This procedure was used by a team of designers in the New Orleans District for the Lake Pontchartrain and Vicinity Hurricane Protection Project and the West Bank and Vicinity, Hurricane Protection Project in conjunction with the post-Katrina restoration and the 100-year levee designs specified by Congress in connection with the levee restoration work. The LACPR 100-year automated design process produced design results that are consistent with work done by the restoration design team that used the step-wise procedure.

Step 5 of the step-wise procedure, which calls for a check for design resiliency for the 500-year exceedence event, was eliminated in the LACPR work. This check was not necessary for the level of design detail needed for plan comparisons for LACPR. The LACPR design effort was based on a simplification of the process. Levee design was composed of a wave berm located at the still water level with a 1 on 4 slope for that portion of the levee above the still water level. The process that was used for the 100-year design effort was much more rigorous and involved different levee slopes, floodwalls, and slope protection; therefore, being sure that each component of the system provided the same resiliency was a necessary step.

Hydromodeling Step 1: Surge Levels and Wave Characteristics

The numerical computations for the surge levels and the wave characteristics were carried out with two numerical models: ADCIRC for surge levels and WAM/STWAVE for the wave characteristics. These are state-of-the-art models and are also being applied to the IPET analyses and 100-year design study for the hurricane risk reduction system around New Orleans.

A set of hurricane conditions have been evaluated with the modeling suite ADCIRC/STWAVE for the base condition. The modeled storms are different in terms of the hurricane tracks, minimum pressure, and radius, among others. The base condition consists of the existing bathymetric and topographic condition, reflecting wetlands, and authorized navigation features, as previously described in Section 4. The different levee alignments were then modeled to evaluate the behavior of the surge levels and waves. In addition, computations have been carried out to evaluate the future effects of relative sea level rise and marsh improvement/degradation.

Hydromodeling Step 2: Frequency Analysis

Based on the results from ADCIRC and STWAVE in Step 1, a frequency analysis was performed to determine the surge levels and wave characteristics for different return periods. The method adopted for the frequency analysis is the Joint Probability Method with Optimal Sampling (JPM-OS) that takes into account the joint probability of forward speed, size, minimum pressure, angle of approach, and geographic distribution of the hurricanes. In order to establish the frequency curves for surge and waves, 152 storms were modeled. For these alternatives the number of storms that were evaluated has been reduced to 56 storms; the remaining storms were established using correlation techniques in order to carry out the frequency analysis with the JPM-OS method.

The frequency analysis has resulted in stage frequencies for the exterior areas, i.e. the areas that are not protected by the levees. Furthermore, this analysis has provided the surge levels and the wave characteristics for different return periods along the levee system as needed for the levee design and overtopping volumes in Step 3.

Hydromodeling Step 3: Levee Design and Overtopping Volumes

To provide a range of alternatives for evaluation and to enable the economic evaluation, each levee alternative was evaluated for different risk reduction levels and event frequencies. A levee design was made for three different levels of risk reduction (100-year, 400-year, and 1000-year). Given the level of risk reduction, the overtopping volumes were computed for four return periods of the outside surge level and wave characteristics (100-year, 400-year, 1000-year and 2000-year). The 2000-year return period was necessary to establish at least three points on the interior stage frequency curve for alternatives designed at the 1000-year risk reduction level.

In short, this procedure has been applied as follows in LACPR:

- Use the surge level and wave characteristics at the levees for a given level of risk reduction (e.g. 100-year) and assume a simplified levee design for this planning effort, i.e. a levee with a wave berm at the still water (storm surge) level and a constant slope near the crest of the levee of 1:4.
- Determine the overtopping rate using empirical formulations. A Monte Carlo Simulation was adopted to compute the uncertainty in the overtopping rate given the uncertainties in the hydraulic boundary conditions and the empirical coefficients in the overtopping formulations.
- Establish the levee height in such a way that the overtopping rate is less than 0.1 cubic feet per second per foot with a 90 percent confidence level.

The levee heights for the various alternatives have been used as an input for the costs estimates. The overtopping volumes were computed using the information on the surge level hydrographs from ADCIRC. Based on a statistical analysis, a correlation was established between the duration of the surge and the maximum surge level. This correlation has been applied to compute the overtopping rate during the storm assuming that the wave characteristics are constant around the peak of the storm.

Hydromodeling Step 4: Interior Stage Frequency

The final step was to determine the interior stage frequency for each economic subunit. A stage-storage curve has been established for each subunit. This information has been extracted from existing rainfall-runoff models or from LIDAR data for these areas. The interior stage frequency has been based on the sum of the overtopping volume from step 3 together with the ten-year rainfall in the subunit. The effect of pumping has been taken into account if applicable.

The stage-storage approach effectively fills the lowest areas first and does not capture the dynamic effects needed for temporal and areal flood predictions. Therefore, when using stage-storage flood level predictions to estimate annualized damages, the precision of the estimate necessarily suffers when compared to a more rigorous modeling approach. When comparing alternative plans with structural measures against each other in terms of risk reduction, risk associated with the rainfall event is constant for all plans and does not bias the comparison.

Hydromodeling Outputs

Hydromodeling outputs were used to determine the probability of damage inside and outside the proposed levee system as well as the desired height and related cost of structural improvements for each of the alternative plans.

Outputs of the hydromodeling process were used to develop metrics for the evaluation and comparison of the alternative plans. For example, storm-stage frequencies (the percent chance that a specific inundation level is expected to occur for a given return period) in combination with stage-damage relationships (damage expected for a given inundation level), were used to estimate residual damages, which is one of the economic metrics described in the next section.

Confidence Levels

The levels of confidence in predicted water level for a given frequency of storm was set at the 10%, 50% and 90% and achieved statistically.

Vertical Controls and Datum

The issue of vertical datum has plagued the engineering and surveying community in Southern Louisiana. Fortunately, in the last few years the change to NAVD 88 has reduced the uncertainties due to datum issues to a large extent. All elevations referenced in the LACPR report are in NAVD 88 2004.65 datum. That being said, there are still many problems associated with trying to convert historical data such as gauge data, high water mark data, etc. into the new datum since the historical data is composed of a hodge-podge of datum spanning numerous leveling epochs. The NAVD 88 datum will be used as the reference for all elevations in the report unless otherwise stated as being a different datum.

Categories of Metrics

Metrics were developed and used to evaluate alternative plans to establish the degree to which they satisfy the planning objectives. One or more metrics is used to measure performance against each of the five LACPR planning objectives. The metrics can also be categorized by the four traditional planning accounts as follows:

- **National Economic Development (NED)** - Displays changes in the economic value of the national output of goods and services.
- **Regional Economic Development (RED)** - Displays changes in the distribution of regional economic activity (e.g., income and employment).
- **Environmental Quality (EQ)** - Displays non-monetary effects on ecological, cultural, and aesthetic resources including the positive and adverse effects of ecosystem restoration plans.
- **Other Social Effects (OSE)** - Displays plan effects on social aspects such as community impacts, health and safety, displacement, energy conservation and others.

Metrics involve quantification of a complex array of human and natural system drivers.

Effective Metrics

Effective metrics must be scientifically verifiable, easy to communicate to a wide audience, credible, scalable, relevant, sensitive enough to capture the minimum meaningful level of change, minimally redundant, and transparent.

Therefore, any set of metrics will not be representative of all the decision factors that could be brought to bear on the problem. For this reason, metrics are often referred to as indicators that emphasize the representational relationship between elements of complex systems. They are indicative, but not definitive, gauges and consequently must be interpreted with their limitations in mind.

The list of metrics developed to conduct plan evaluations are presented in **Table 6-1**. These metrics will be used to score and then rank flood and storm risk reduction measures and plans within each future scenario. In selecting this set of metrics, the LACPR team is striving to represent the best available information for evaluating alternatives, keeping in mind the characteristics of effective metrics.

Metric estimates can be derived from mathematical models, empirical data, or expert opinion, and will be supported by descriptions of the important underlying assumptions associated with their use. In addition, estimates of uncertainty for metric values will be quantified (e.g., in terms of the variance or range associated with the estimate) to support risk informed decisions.

Table 6-1. LACPR planning objectives and related metrics.

Planning Objective	Metrics
National Economic Development Metrics	
Reduce damages from catastrophic storm inundation (that impact the National economy)	Residual Damages
	Life-cycle Cost
	Construction Time
Environmental Quality Metrics	
Promote a sustainable coastal ecosystem	Spatial Integrity
Restore and sustain diverse fish and wildlife habitats	Direct Wetland Impacts
	Wetland Created and/or Protected
	Indirect Impacts
Sustain the unique heritage of coastal Louisiana by protecting cultural resources	Historic Properties Protected
	Archaeological Sites Protected
Regional Economic Development Metrics	
Reduce damages from catastrophic storm inundation (that impact the regional economy).	Gross Regional Output Impacted
	Employment Impacted
	People's Earned Income Impacted
Other Social Effects Metrics	
Reduce risk to public health and safety from catastrophic storm inundation.	Residual Population Impacted
Sustain the unique heritage of coastal Louisiana by protecting cultural resources and supporting traditional and ethnic communities	Historic Districts Protected

National Economic Development Metrics

Three metrics fall into the National Economic Development (NED) account. The NED account displays changes in the economic value of the national output of goods and services.

Residual Damages

Units: Annual equivalent dollars
Goal: Minimize residual damages
Data Source: USACE feasibility studies, Hazard U.S.-Multi-Hazard database, Louisiana Department of Labor, National Agricultural Statistics Service, Calthorpe Associates, and Moody’s Economy.com
Description: Regardless of the level of protection, no alternative will provide total protection against all potential storms over the entire period of analysis (2010-2075). Each alternative has been evaluated to determine the remaining potential damage associated with these storms over a planning period of 65 years. The metric reflects the potential attached to an alternative for reducing potential damage.

Residual damages are a measure of the remaining dollar damages to assets in each planning subunit expressed in annual terms for any alternative. The equivalent annual damage value includes damages to residential and non-residential properties, emergency losses, losses to agricultural resources, and damages to the transportation infrastructure. More details on this metric can be found in the *Economics Appendix*.

Life-cycle Cost

Units: Present value dollars
Goal: Minimize life-cycle cost
Data Source: USACE engineering
Description: Life-cycle costs represent the total cost of an alternative and include the following:

- Engineering and design costs;
- Cost of materials and construction of physical structures;
- Construction management costs;
- Real estate costs;
- Facility relocation costs;
- Operations, maintenance, repair, replacement, and rehabilitation costs.

Mitigation costs are not included in the life-cycle costs at this time. Mitigation costs would be accounted for once specific projects are identified. The life-cycle cost metric does not include adaptive management or monitoring costs; however, it does include costs associated with maintaining the risk reduction levels of structural measures into the future associated with relative sea level rise and/or degradation of the coast, i.e. future levee lifts.

The life-cycle costs for each alternative are discounted to the base year of 2025 for the purpose of a common comparison. At the end of the 50-year period of analysis a zero residual value is assumed, which equates to an assumption that the system would have to be rebuilt in 50 years.

The cost estimates were developed using post-Hurricane Katrina impacts to labor, equipment, materials, and supplies. The estimated costs were based upon an analysis of each line item evaluating quantity, production rate, and time, together with the appropriate equipment, labor, and material costs. All cost estimates include a 25 percent contingency.

Details on the cost assumptions for the structural and coastal restoration plan components can be found in the *Engineering Appendix*. Details on the nonstructural plan cost assumptions can be found in the *Nonstructural Plan Component Appendix*.

Construction Time

Units: Total number of years
Goal: Minimize construction time
Data Source: USACE engineering
Description: The construction time metric is an estimation of the length of time to complete construction of a particular alternative. The following assumptions were applied to the construction time metrics for the various categories of alternatives:

- **Coastal restoration only plans** have a metric value for construction time of 15 years, which consists of the following:
  - 25 years for shoreline protection (Planning Unit 4 only), marsh creation and ridge restoration
  - 15 years for diversions, relocation of navigation channels, and bypass channels
  - 10 years for shoreline protection (Planning Units 1, 2, and 3b only) and barrier islands
  - 5 years for fresh water redistribution
- **Nonstructural/coastal restoration plans** have a metric value for construction time of 15 years, which is based on the nonstructural component.
- **Structural/coastal restoration plans** and **comprehensive plans** have a metric value for construction time which is based only on the structural component of the plans.

Environmental Quality Metrics

The Environmental Quality (EQ) account displays non-monetary effects on ecological, cultural, and aesthetic resources including the positive and adverse effects of alternative plans. The first four metrics relate to either environmental benefits of coastal restoration alternatives or adverse environmental effects from the implementation of structural alternatives. The last two metrics relate to cultural resources.

Spatial Integrity

Units: Unitless (scaled 0 to 1)
Goal: Maximize spatial integrity
Data Source: Models, empirical data, maps, and best professional judgment
Description: The size, shape, density, configuration and structure of the landscape across an area or region affect fundamental ecosystem processes, which determine the trajectories of ecological condition. Spatial integrity refers to undivided, contiguous space. A fragmented landscape (one containing several discrete patches of land or many inclusions of water) has less spatial integrity than a landscape containing fewer patches or inclusions.

Spatial integrity is measured using a Landscape Stability Index which ranges from 0 to 1, with probability of land retention increasing as the index approaches 1. The Landscape Stability Index places emphasis not only on the amount of land built, but the spatial configuration of that land.

Direct Wetland Impacts

Units: Total number of acres
Goal: Minimize direct wetland impacts
Data Source: Models, empirical data
Description: Many of the proposed levee alignments cross wetlands and result in the direct loss of those wetlands occupied by the footprint of the levee and adjacent borrow areas. The magnitude of the impact is a function of the levee alignment and the level of protection, which influences levee base width.

The potential direct wetland losses are calculated by simply overlaying the footprint of a given levee and associated borrow areas on the existing coastal landscape, assuming that all construction impacts occur simultaneously. These simplifying assumptions produce acreages of potentially adverse direct impacts on wetland.

Wetland Acres Created and/or Protected

Units: Total number of acres
Goal: Maximize wetland acres created and/or protected
Data Source: Models, empirical data
Description: This metric is the direct measure of wetlands created and/or restored and those existing wetlands protected form further degradation. Wetlands created and/or restored included mechanical marsh creation and diversion of sediments and nutrients.

A high weighting rewards plans that have significant wetland creation and/or protection compared to the anticipated loss of wetlands projected over the period of analysis in the no-action scenario.

Indirect Impacts

Units: Unitless (scaled -8 to +8)
Goal: Minimize indirect impacts
Data Source: Best professional judgment and pertinent scientific literature.
Description: This metric compares levee alignments and their potential, indirect impacts (both positive and negative) to wetlands and other aquatic resources. Indirect impacts considered include (1) hydrologic changes, (2) effects on fisheries, (3) potential to induce development in wetlands, and (4) consistency with coastal restoration. Rankings range from +8 to -8, with a positive ranking meaning that there is the potential for beneficial effects to wetlands.

Hydrologic impacts are potential changes, such as reduced or increased impoundment; reduced or increased sheet flow; and reduced or increased salinities. In applying rankings, the team considered the amount of wetlands that would be enclosed within a proposed levee system.

Fishery impacts are potential reductions in fish access due to increased velocities and/or physical barriers; increases in fish access due to removal of obstructions; and/or reductions or increases in fish habitat.

Induced development is the potential increase or decrease in wetland areas with significantly improved hurricane protection and which are susceptible to residential, recreational and/or commercial development.

Ecological sustainability/consistency (with coastal restoration) is the extent to which the proposed levee is or is not likely to be consistent with existing and future coastal restoration projects, particularly river reintroduction projects (a.k.a. diversions). This also refers to the extent to which the proposed levee may or may not be located in a potentially sustainable environment.

Historic Properties Protected

Units: Total number of properties
Goal: Maximize historic properties protected
Data Source: Surveys and registers
Description: The number of historic properties includes properties eligible or listed on the National Register and National Historic Landmarks. While archaeological sites may fall into any of these categories, structures form an overwhelming majority. In general, cultural resources in these categories must meet criteria defined at a local or national level to be included. Examples of historic resources in this category include Fort Jackson, Oaklawn Manor, Jackson Square, and the Garden District. The analysis takes into consideration processes that may protect historic properties as well as processes that may damage or destroy properties, such as land loss, erosion, and flooding and the negative impacts the processes have on different properties. More details on this metric can be found in the *Cultural Resources Appendix.*

Archaeological Sites Protected

Units: Total number of sites
Goal: Maximize archaeological sites protected
Data Source: Surveys and registers
Description: Archaeological sites include locations with artifacts and other materials from people and cultures from the prehistoric and historic past. Archaeological sites may include the remains of buildings, trash pits, hearths, pottery, and tools (stone, metal, and other materials). The analysis takes into consideration processes that may protect archaeological sites as well as processes that may damage or destroy sites such as land loss, erosion, and flooding and the negative impacts the processes have on different sites. More details on this metric can be found in the *Cultural Resources Appendix.*

Regional Economic Development Metrics

Three metrics were developed to assess the impacts of a storm event on the regional economy based on the criteria of the Regional Economic Development (RED) account. These metrics include gross regional output, number of people employed, and average earned income. Indirect impacts, such as the reduced customer base following a storm event and the closing of related businesses, are not currently considered by the metrics for the RED account. However, these indirect impacts will be considered when the REMI model (Regional Economic Model Incorporated) becomes available. More details on these metrics and the REMI model can be found in the *Economics Appendix*.

The output, or sales, employment, and earned income associated with each commercial property in a census block under the no action condition and for each alternative are assumed to be affected whenever the stage associated with a frequency storm event at the planning subunit level reaches or exceeds the first floor elevation of the structure. Data were developed for five frequency events (10-year, 100-year, 400-year, 1,000-year, and 2,000 year) to derive the expected annual values. These expected annual values were converted to an equivalent annual value using the Federal discount rate.

Gross Regional Output Impacted

Units: Annual equivalent dollars
Goal: Minimize gross regional output impacted
Data Source: North American Industry Classification System, IPET, Louisiana Department of Labor, Calthorpe Associates
Description: The metric assesses the effects of alternatives on the planning unit's economic output. The direct impact on sales, by the commercial establishments in the planning area is based on the employment-to-output ratio.

Employment Impacted

Units: Annual equivalent number of people
Goal: Minimize employment impacted
Data Source: Louisiana Department of Labor, Calthorpe Associates
Description: This metric assesses the effects of alternatives upon employment based on data provided by the Louisiana Department of Labor adjusted annually for the period of analysis using population and employment projections.

People's Earned Income Impacted

Units: Annual equivalent dollars
Goal: Minimize people's earned income impacted
Data Source: Louisiana Department of Labor
Description: The metric assesses the effects of alternatives on individual income. The direct impacts on employment and wages were based on data provided by the Louisiana Department of Labor adjusted annually through the period of analysis using the population and employment projections.

Other Social Effects Metrics

Two metrics fall into the Other Social Effects (OSE) account, which displays plan effects on social aspects, such as community impacts, health and safety, displacement, energy conservation and others.

Residual Population Impacted

Units: Annual equivalent number of people
Goal: Minimize residual population impacted

Data Source: U.S. Census, Calthorpe Associates
Description: This metric was developed to assess the ability of alternatives to protect the health and safety of the public from a storm event. The impacted population is defined as the total number of residents in each census block in which the stage associated with a frequency storm event is greater than the mean ground elevation of that census block. The population metric does not consider the portion of the population that would evacuate before a storm event. Data were developed for five frequency events (10-year, 100-year, 400-year, 1,000-year, and 2,000 year) to derive the expected annual values. These expected annual values were converted to an equivalent annual value using the Federal discount rate. More details on this metric can be found in the *Economics Appendix*.

Historic Districts Protected

Units: Total number of historic districts
Goal: Maximize historic districts protected.
Data Source: Surveys and registers
Description: Historic districts encompass living communities – not inanimate cultural records – consisting of clusters of historic buildings and structures that share a similar date or theme. Historic districts reflect the historic development in an area, help connect people to the past, contribute to the regional landscape, and serve to create a sense of place. Protecting historic districts helps to preserve the unique historic character of towns, neighborhoods, and rural settings, and conserve data that provides information about the past.

Historic districts may be urban neighborhoods, commercial districts, or rural landscapes, helping to define people's sense of place. In general, it's the collection of the properties that make historic districts important, and they can be viewed as the sum being greater than the parts. Examples of historic districts include the French Quarter, the Garden District, and the Abbeville Residential Historic District.

The number of historic districts protected by each alternative is determined through a process of collecting information on recorded districts, identifying the processes that may damage or destroy sites, and developing a GIS database to compute the number of protected sites. The GIS analysis takes into consideration processes such as land loss, erosion, and depth of flooding and the negative impacts these processes have on the historic districts. More details on this metric can be found in the *Cultural Resources Appendix.*

Summary of Plan Evaluation Considerations

The results of the metric evaluation will be used to inform the decision analysis. Metric results are being developed for each alternative across a range of four future scenarios. **Table 6-2** presents a summary of plan evaluation parameters, which are described elsewhere in this document and/or the appendices:

Table 6-2. Summary of plan evaluation considerations.

Parameter or Case	Variations
Design Levels	100-year risk reduction design
	400-year risk reduction design
	1000-year risk reduction design
Flooding Events	10-year rainfall event
	100-year surge event
	400-year surge event
	1000-year surge event
	2000-year surge event
Water Level Confidence Limits	10%
	50%
	90%
STWAVE Modeling	With friction
	Without friction
Coastal Landscape	Existing/maintain
	Degraded
Future Relative Sea Level Rise	Projection 1 based on IPCC rates
	Projection 2 based on NRC rates
Redevelopment Rates	High employment, dispersed land use
	Business as usual, compact land use
Hydrologic Conditions	Existing/base (approximately 2010)
	Future (approximately 2060)
Economic Conditions	Base year (2025)
	End of period of analysis (2075)

Preliminary Evaluation Results

The previous sections briefly described each metric and how it is evaluated. **Table 6-3** through **Table 6-7** presents preliminary data in the form of metric values to give a better understanding of the type of data that will be used to rank alternatives. Metric values are an essential component of the multi-criteria decision analysis. Another important component is how stakeholders weight each metric, which will be described in the next section on comparison of alternatives. The metric results and stakeholder weights are combined to score and then rank the alternative flood and storm damage reduction plans. The multi-criteria decision analysis tool helps to ensure that the process of plan selection is a transparent and rational one.

For the evaluation, quantitative values are being developed for each of the 14 metrics for each of the 109 alternatives across a range of four future scenarios as previously described. The complete set of hydrologic and metric results are included in the *Evaluation Results Appendix*. To summarize the preliminary results for this report, the metric results are presented for two cases in each planning unit: 1) the no action (or without-project) alternative in the top section of each table and 2) the range of all with-project alternatives in the bottom section of each table.

For the with-project alternatives, the low value represents the lowest metric result for any alternative within the planning unit, and the high value represents the highest metric result for any alternative within the planning unit. Therefore, the low and high values represent the most extreme metric results generated across the range of all with-project alternatives within the planning unit.

Only the metric results based on a high (90%) confidence limit on water surface elevations are presented in the tables, however, metric values are also being developed for low (10%) and medium (50%) confidence limits. All of these metric values will be considered in the decision analysis in order to incorporate the uncertainty associated with water level predictions.

The metric results for resident population impacted, residual damages, gross regional output, employment impacted, and people's earned income impacted are presented as annual equivalents so they are significantly lower than if an actual event such as Hurricane Katrina were to occur again.

For stakeholders and decision makers to become fully engaged in the decision process for LACPR, they should become familiar with these tables to get a general idea of how metric values could vary between the no action alternative and various with-project alternatives, as well as how metric values vary between the planning units. The variation between metric values can give stakeholders and decision makers a better understanding of how they should allocate weights to the various metrics to get the best results. For example, if a metric value doesn't vary much between alternatives, then allocating a large proportion of weight to that metric may not affect the ranking of plans as much as allocating a large proportion of weight to a metric that has a wide variation in metric values. The next section will provide an example of how the multi-criteria decision analysis will be performed for LACPR.

Table 6-3. Summary of metric results for Planning Unit 1.

(No Action Alternative)

	Metric Value Range Based on High (90%) Confidence Limit on Water Surface Elevations	Metric Results Related Directly to Hydromodeling - Surge Elevations							
		Resident Population Impacted	Residual Damages	Gross Regional Output Impacted	Employment Impacted	People's Earned Income Impacted	Archeo. Sites Protected	Historic Properties Protected	Historic Districts Protected
		Ann. Equiv. # 1,000's	Ann. Equiv ($ millions)	Ann. Equiv ($ millions)	Ann. Equiv # 1,000's	Ann. Equiv ($ millions)	# Sites	# Properties	# Districts
Scenario 1	No Action	70.1	2,415	2,674	10.0	707	102	130	50
Scenario 2	No Action	73.6	2,873	3,980	13.1	1,002	102	130	50
Scenario 3	No Action	58.2	2,305	1,981	8.3	574	102	130	50
Scenario 4	No Action	60.7	2,758	3,083	10.7	803	102	130	50

	Metric Value Range	Metric Results Not Directly Related to Hydromodeling - Surge Elevations							
		Direct Wetland Impacts (acres)	Indirect Impacts	Spatial Integrity	Wetlands Created/ Protected (acres)	Present Value - Life Cycle Costs			Construction Period (years)
						Coastal Component ($ Billions)	Nonstruct Component ($ Billions)	Structural Component ($Billions)	
	No Action	N/A	N/A	0.326	N/A	N/A	N/A	N/A	N/A

(With-Project Conditions - All Alternatives)

	Metric Value Range Based on High (90%) Confidence Limit on Water Surface Elevations	Metric Results Related Directly to Hydromodeling - Surge Elevations							
		Resident Population Impacted	Residual Damages	Gross Regional Output Impacted	Employment Impacted	People's Earned Income Impacted	Archeo. Sites Protected	Historic Properties Protected	Historic Districts Protected
		Ann. Equiv. # 1,000's	Ann. Equiv ($ millions)	Ann. Equiv ($ millions)	Ann. Equiv # 1,000's	Ann. Equiv ($ millions)	# Sites	# Properties	# Districts
Scenario 1	Low	50.8	682	421	2.1	108	261	134	51
	High	65.2	2,142	2,055	8.0	532	303	159	52
Scenario 2	Low	51.4	689	433	2.1	111	261	134	51
	High	66.3	2,219	2,213	8.4	566	303	159	51
Scenario 3	Low	46.6	672	385	2.1	111	261	134	51
	High	54.8	2,075	1,558	7.0	449	303	159	52
Scenario 4	Low	47.0	677	393	2.1	114	261	134	51
	High	55.6	2,158	1,706	7.2	471	303	159	51

	Metric Value Range	Metric Results Not Directly Related to Hydromodeling - Surge Elevations							
		Direct Wetland Impacts (acres)	Indirect Impacts	Spatial Integrity	Wetlands Created/ Protected (acres)	Present Value - Life Cycle Costs			Construction Period (years)
						Coastal Component ($ Billions)	Nonstruct Component ($ Billions)	Structural Component ($Billions)	
	Low	-980	-8	0.445	214,700	✳	✳	✳	14
	High	-10,081	-1	0.478	239,200	✳	✳	✳	16

NOTES:
Scenario 1- Low Relative Sea Level Rise (RSLR), High Employment, Dispersed Population**; Scenario 2 -** High RSLR, High Employment, Dispersed Population; **Scenario 3** - Low RSLR, Business-As-Usual, Compact Population**; Scenario 4** - High RSLR, Business-As-Usual, Compact Population.

Metric Values have also been developed for Low (10%) and Medium (50%) Confidence Limits for water surface elevations for use in Multi-Criteria Decision Analysis (MCDA).

✳ The Present Value of the Life Cycle Costs for each Plan Component in Planning Unit 1 varies from a low of $2 to $3 billion for some of the nonstructural components to a high of $10's of billions for some of the structural components. Currently these costs are based on parametric costs for puposes of screening of alternatives and relative comparison of all with-project conditions. Specific report recommendations addressed in the final technical report will be based on more detailed cost estimates included in a MCACES cost format. **Based on a normalized cost value (scaled 0-100) across all project components for all Planning Units, the low and high values for coastal components for Planning Unit 1 vary from approximately 16 to 27; for nonstructural components from 4 to 87; and for structural components from 12 to 100.**

Table 6-4. Summary of metric results for Planning Unit 2.

(No Action Alternative)

	Metric Value Range Based on High (90%) Confidence Limit on Water Surface Elevations	Metric Results Related Directly to Hydromodeling - Surge Elevations							
		Resident Population Impacted	Residual Damages	Gross Regional Output Impacted	Employment Impacted	People's Earned Income Impacted	Archeo. Sites Protected	Historic Properties Protected	Historic Districts Protected
		Ann. Equiv. # 1,000's	Ann. Equiv ($ millions)	Ann. Equiv ($ millions)	Ann. Equiv # 1,000's	Ann. Equiv ($ millions)	# Sites	# Properties	# Districts
Scenario 1	**No Action**	37.0	2,372	3,750	8.6	698	54	16	3
Scenario 2	**No Action**	37.1	2,415	3,829	8.7	709	54	14	3
Scenario 3	**No Action**	28.1	1,892	3,060	6.9	554	54	16	3
Scenario 4	**No Action**	28.2	1,932	3,133	6.9	566	54	14	3

	Metric Value Range	Metric Results Not Directly Related to Hydromodeling - Surge Elevations							
		Direct Wetland Impacts (acres)	Indirect Impacts	Spatial Integrity	Wetlands Created/ Protected (acres)	Present Value - Life Cycle Costs			Construction Period (years)
						Coastal Component ($ Billions)	Nonstruct Component ($ Billions)	Structural Component ($Billions)	
	No Action	N/A	N/A	0.361	N/A	N/A	N/A	N/A	N/A

(With-Project Conditions - All Alternatives)

	Metric Value Range Based on High (90%) Confidence Limit on Water Surface Elevations	Metric Results Related Directly to Hydromodeling - Surge Elevations							
		Resident Population Impacted	Residual Damages	Gross Regional Output Impacted	Employment Impacted	People's Earned Income Impacted	Archeo. Sites Protected	Historic Properties Protected	Historic Districts Protected
		Ann. Equiv. # 1,000's	Ann. Equiv ($ millions)	Ann. Equiv ($ millions)	Ann. Equiv # 1,000's	Ann. Equiv ($ millions)	# Sites	# Properties	# Districts
Scenario 1	**Low**	15.6	320	226	0.6	34	266	16	5
	High	27.8	1,619	1,925	4.5	313	502	27	9
Scenario 2	**Low**	15.7	33	244	0.6	36	266	14	5
	High	27.9	1,656	1,945	4.5	309	502	27	9
Scenario 3	**Low**	12.6	200	267	0.8	5	266	16	5
	High	20.9	1,175	1,613	3.7	253	502	27	9
Scenario 4	**Low**	12.6	205	283	0.8	47	266	14	5
	High	21.0	1,205	1,648	3.7	256	502	27	9

	Metric Value Range	Metric Results Not Directly Related to Hydromodeling - Surge Elevations							
		Direct Wetland Impacts (acres)	Indirect Impacts	Spatial Integrity	Wetlands Created/ Protected (acres)	Present Value - Life Cycle Costs			Construction Period (years)
						Coastal Component ($ Billions)	Nonstruct Component ($ Billions)	Structural Component ($Billions)	
	Low	min to -704	-8	0.535	106,000	✳	✳	✳	6
	High	-9,458	4	0.544	135,300	✳	✳	✳	15

NOTES:
Scenario 1- Low Relative Sea Level Rise (RSLR), High Employment, Dispersed Population**; Scenario 2 -** High RSLR, High Employment, Dispersed Population; **Scenario 3** - Low RSLR, Business-As-Usual, Compact Population**; Scenario 4** - High RSLR, Business-As-Usual, Compact Population.

Metric Values have also been developed for Low (10%) and Medium (50%) Confidence Limits for water surface elevations for use in Multi-Criteria Decision Analysis (MCDA).

✳ The Present Value of the Life Cycle Costs for each Plan Component in Planning Unit 2 varies from a low of $3 to $4 billion for some of the nonstructural components to a high of $10's of billions for some of the structural components. Currently these costs are based on parametric costs for puposes of screening of alternatives and relative comparison of all with-project conditions. Specific report recommendations addressed in the final technical report will be based on more detailed cost estimates included in a MCACES cost format. **Based on a normalized cost value (scaled 0-100) across all project components for all Planning Units, the low and high values for coastal components for Planning Unit 2 vary from approximately 26 to 32; for nonstructural components from 6 to 69; and for structural components from 1 to 75.**

Table 6-5. Summary of metric results for Planning Unit 3a.

(No Action Alternative)

Metric Results Related Directly to Hydromodeling - Surge Elevations

	Metric Value Range Based on High (90%) Confidence Limit on Water Surface Elevations	Resident Population Impacted (Ann. Equiv. # 1,000's)	Residual Damages (Ann. Equiv ($ millions))	Gross Regional Output Impacted (Ann. Equiv ($ millions))	Employment Impacted (Ann. Equiv # 1,000's)	People's Earned Income Impacted (Ann. Equiv ($ millions))	Archeo. Sites Protected (# Sites)	Historic Properties Protected (# Properties)	Historic Districts Protected (# Districts)
Scenario 1	No Action	32.9	2,712	3,465	11.3	704	92	7	1
Scenario 2	No Action	33.0	2,828	3,638	11.8	750	92	5	1
Scenario 3	No Action	28.9	2,340	3,013	9.8	601	92	7	1
Scenario 4	No Action	29.0	2,460	3,155	10.3	640	92	5	1

Metric Results Not Directly Related to Hydromodeling - Surge Elevations

	Metric Value Range	Direct Wetland Impacts (acres)	Indirect Impacts	Spatial Integrity	Wetlands Created/ Protected (acres)	Present Value - Life Cycle Costs: Coastal Component ($ Billions)	Present Value - Life Cycle Costs: Nonstruct Component ($ Billions)	Present Value - Life Cycle Costs: Structural Component ($Billions)	Construction Period (years)
	No Action	N/A	N/A	0.345	N/A	N/A	N/A	N/A	N/A

(With-Project Conditions - All Alternatives)

Metric Results Related Directly to Hydromodeling - Surge Elevations

	Metric Value Range Based on High (90%) Confidence Limit on Water Surface Elevations	Resident Population Impacted (Ann. Equiv. # 1,000's)	Residual Damages (Ann. Equiv ($ millions))	Gross Regional Output Impacted (Ann. Equiv ($ millions))	Employment Impacted (Ann. Equiv # 1,000's)	People's Earned Income Impacted (Ann. Equiv ($ millions))	Archeo. Sites Protected (# Sites)	Historic Properties Protected (# Properties)	Historic Districts Protected (# Districts)
Scenario 1	Low	14.9	970	897	4.0	194	92	7	1
	High	32.9	2,693	3,425	11.2	699	203	18	1
Scenario 2	Low	15.1	1,028	984	4.2	211	92	5	1
	High	33.0	2,816	3,638	11.8	750	203	18	1
Scenario 3	Low	13.3	825	804	3.4	158	92	7	1
	High	28.9	2,318	2,981	9.8	597	203	18	1
Scenario 4	Low	13.4	871	868	3.5	171	92	5	1
	High	29.0	2,447	3,154	10.3	640	203	18	1

Metric Results Not Directly Related to Hydromodeling - Surge Elevations

	Metric Value Range	Direct Wetland Impacts (acres)	Indirect Impacts	Spatial Integrity	Wetlands Created/ Protected (acres)	Present Value - Life Cycle Costs: Coastal Component ($ Billions)	Present Value - Life Cycle Costs: Nonstruct Component ($ Billions)	Present Value - Life Cycle Costs: Structural Component ($Billions)	Construction Period (years)
	Low	-4,200	-5	0.525	107,700	✳	✳	✳	10
	High	-6,600	-5	0.525	110,000	✳	✳	✳	15

NOTES:
Scenario 1- Low Relative Sea Level Rise (RSLR), High Employment, Dispersed Population**; Scenario 2 -** High RSLR, High Employment, Dispersed Population; **Scenario 3** - Low RSLR, Business-As-Usual, Compact Population**; Scenario 4** - High RSLR, Business-As-Usual, Compact Population.

Metric Values have also been developed for Low (10%) and Medium (50%) Confidence Limits for water surface elevations for use in Multi-Criteria Decision Analysis (MCDA).

✳ The Present Value of the Life Cycle Costs for each Plan Component in Planning Unit 3a varies from a low of about $1 billion for some of the nonstructural components to a high of $10's of billions for some of the structural components. Currently these costs are based on parametric costs for puposes of screening of alternatives and relative comparison of all with-project conditions. Specific report recommendations addressed in the final technical report will be based on more detailed cost estimates included in a MCACES cost format. **Based on a normalized cost value (scaled 0-100) across all project components for all Planning Units, the low and high values for coastal components for Planning Unit 3a vary from approximately 41 to 42; for nonstructural components from 1 to 26; and for structural components from 33 to 49.**

Table 6-6. Summary of metric results for Planning Unit 3b.

(No Action Alternative)

	Metric Value Range Based on High (90%) Confidence Limit on Water Surface Elevations	Metric Results Related Directly to Hydromodeling - Surge Elevations							
		Resident Population Impacted	Residual Damages	Gross Regional Output Impacted	Employment Impacted	People's Earned Income Impacted	Archeo. Sites Protected	Historic Properties Protected	Historic Districts Protected
		Ann. Equiv. # 1,000's	Ann. Equiv ($ millions)	Ann. Equiv ($ millions)	Ann. Equiv # 1,000's	Ann. Equiv ($ millions)	# Sites	# Properties	# Districts
Scenario 1	**No Action**	11.8	855	830	2.9	176	19	13	1
Scenario 2	**No Action**	12.3	908	902	3.0	190	19	11	1
Scenario 3	**No Action**	11.1	793	909	2.9	182	19	13	1
Scenario 4	**No Action**	11.7	840	980	3.1	194	19	11	1

	Metric Value Range	Metric Results Not Directly Related to Hydromodeling - Surge Elevations							
		Direct Wetland Impacts (acres)	Indirect Impacts	Spatial Integrity	Wetlands Created/ Protected (acres)	Present Value - Life Cycle Costs: Coastal Component ($ Billions)	Present Value - Life Cycle Costs: Nonstruct Component ($ Billions)	Present Value - Life Cycle Costs: Structural Component ($Billions)	Construction Period (years)
	No Action	N/A	N/A	0.390	N/A	N/A	N/A	N/A	N/A

(With-Project Conditions - All Alternatives)

	Metric Value Range Based on High (90%) Confidence Limit on Water Surface Elevations	Metric Results Related Directly to Hydromodeling - Surge Elevations							
		Resident Population Impacted	Residual Damages	Gross Regional Output Impacted	Employment Impacted	People's Earned Income Impacted	Archeo. Sites Protected	Historic Properties Protected	Historic Districts Protected
		Ann. Equiv. # 1,000's	Ann. Equiv ($ millions)	Ann. Equiv ($ millions)	Ann. Equiv # 1,000's	Ann. Equiv ($ millions)	# Sites	# Properties	# Districts
Scenario 1	**Low**	5.0	285	198	0.9	41	19	13	1
	High	11.7	835	805	2.9	169	312	20	5
Scenario 2	**Low**	5.1	294	207	0.9	43	19	11	1
	High	12.3	894	863	3.0	183	312	20	5
Scenario 3	**Low**	4.7	202	159	0.7	34	19	13	1
	High	11.0	779	887	2.9	177	312	20	5
Scenario 4	**Low**	4.8	275	212	0.9	41	19	11	1
	High	11.6	829	942	3.0	189	312	20	5

	Metric Value Range	Metric Results Not Directly Related to Hydromodeling - Surge Elevations							
		Direct Wetland Impacts (acres)	Indirect Impacts	Spatial Integrity	Wetlands Created/ Protected (acres)	Present Value - Life Cycle Costs: Coastal Component ($ Billions)	Present Value - Life Cycle Costs: Nonstruct Component ($ Billions)	Present Value - Life Cycle Costs: Structural Component ($Billions)	Construction Period (years)
	Low	-940	-8	0.505	50,000	✳	✳	✳	10
	High	-5,188	4	0.505	62,000	✳	✳	✳	15

NOTES:
Scenario 1- Low Relative Sea Level Rise (RSLR), High Employment, Dispersed Population**; Scenario 2 -** High RSLR, High Employment, Dispersed Population; **Scenario 3** - Low RSLR, Business-As-Usual, Compact Population**; Scenario 4** - High RSLR, Business-As-Usual, Compact Population.

Metric Values have also been developed for Low (10%) and Medium (50%) Confidence Limits for water surface elevations for use in Multi-Criteria Decision Analysis (MCDA).

✳ The Present Value of the Life Cycle Costs for each Plan Component in Planning Unit 3b varies from a low of $0.2 billion for some of the nonstructural components to a high of $10's of billions for some of the structural components. Currently these costs are based on parametric costs for puposes of screening of alternatives and relative comparison of all with-project conditions. Specific report recommendations addressed in the final technical report will be based on more detailed cost estimates included in a MCACES cost format. **Based on a normalized cost value (scaled 0-100) across all project components for all Planning Units, the low and high values for coastal components for Planning Unit 3b vary from approximately 8 to 8; for nonstructural components from 0 to 11; and for structural components from 20 to 55.**

Table 6-7. Summary of metric results for Planning Unit 4.

(No Action Alternative)

	Metric Value Range Based on High (90%) Confidence Limit on Water Surface Elevations	Metric Results Related Directly to Hydromodeling - Surge Elevations							
		Resident Population Impacted	Residual Damages	Gross Regional Output Impacted	Employment Impacted	People's Earned Income Impacted	Archeo. Sites Protected	Historic Properties Protected	Historic Districts Protected
		Ann. Equiv. # 1,000's	Ann. Equiv ($ millions)	Ann. Equiv ($ millions)	Ann. Equiv # 1,000's	Ann. Equiv ($ millions)	# Sites	# Properties	# Districts
Scenario 1	No Action	8.6	760	629	1.5	94	37	1	0
Scenario 2	No Action	9.6	824	744	1.8	121	37	1	0
Scenario 3	No Action	7.5	712	619	1.5	95	37	1	0
Scenario 4	No Action	8.3	762	706	1.7	114	37	1	0

	Metric Value Range	Metric Results Not Directly Related to Hydromodeling - Surge Elevations							
		Direct Wetland Impacts (acres)	Indirect Impacts	Spatial Integrity	Wetlands Created/ Protected (acres)	Present Value - Life Cycle Costs: Coastal Component ($ Billions)	Present Value - Life Cycle Costs: Nonstruct Component ($ Billions)	Present Value - Life Cycle Costs: Structural Component ($Billions)	Construction Period (years)
	No Action	N/A	N/A	0.385	N/A	N/A	N/A	N/A	N/A

(With-Project Conditions - All Alternatives)

	Metric Value Range Based on High (90%) Confidence Limit on Water Surface Elevations	Metric Results Related Directly to Hydromodeling - Surge Elevations							
		Resident Population Impacted	Residual Damages	Gross Regional Output Impacted	Employment Impacted	People's Earned Income Impacted	Archeo. Sites Protected	Historic Properties Protected	Historic Districts Protected
		Ann. Equiv. # 1,000's	Ann. Equiv ($ millions)	Ann. Equiv ($ millions)	Ann. Equiv # 1,000's	Ann. Equiv ($ millions)	# Sites	# Properties	# Districts
Scenario 1	Low	6.0	273	119	0.4	20	37	1	0
	High	8.6	760	629	1.5	94	140	3	0
Scenario 2	Low	5.6	274	119	0.4	20	37	1	0
	High	9.4	803	727	1.7	116	140	3	0
Scenario 3	Low	4.6	260	111	0.4	18	37	1	0
	High	7.4	697	579	1.4	89	140	3	0
Scenario 4	Low	4.9	268	115	0.4	19	37	1	0
	High	8.1	747	694	1.6	111	140	3	0

	Metric Value Range	Metric Results Not Directly Related to Hydromodeling - Surge Elevations							
		Direct Wetland Impacts (acres)	Indirect Impacts	Spatial Integrity	Wetlands Created/ Protected (acres)	Present Value - Life Cycle Costs: Coastal Component ($ Billions)	Present Value - Life Cycle Costs: Nonstruct Component ($ Billions)	Present Value - Life Cycle Costs: Structural Component ($Billions)	Construction Period (years)
	Low	-88	-4	0.575	45,600	✳	✳	✳	10
	High	-2485	-2	0.575	45,700	✳	✳	✳	15

NOTES:
Scenario 1- Low Relative Sea Level Rise (RSLR), High Employment, Dispersed Population**; Scenario 2 -** High RSLR, High Employment, Dispersed Population; **Scenario 3** - Low RSLR, Business-As-Usual, Compact Population**; Scenario 4** - High RSLR, Business-As-Usual, Compact Population.

Metric Values have also been developed for Low (10%) and Medium (50%) Confidence Limits for water surface elevations for use in Multi-Criteria Decision Analysis (MCDA).

✳ The Present Value of the Life Cycle Costs for each Plan Component in Planning Unit 4 varies from a low of about $2 for some of the nonstructural components to a high of $10 + billions for some of the structural components. Currently these costs are based on parametric costs for puposes of screening of alternatives and relative comparison of all with-project conditions. Specific report recommendations addressed in the final technical report will be based on more detailed cost estimates included in a MCACES cost format. **Based on a normalized cost value (scaled 0-100) across all project components for all Planning Units, the low and high values for coastal components for Planning Unit 4 vary from approximately 19 to 19; for nonstructural components from 3 to 10; and for structural components from 4 to 22.**

Section 7. Comparison of Alternatives

This planning step takes the metric results and ranks alternative plans based on various criteria. The application of metric data can be structured in numerous ways as described in the following sections. More details on the comparison of alternatives can be found in the *Risk-Informed Decision Framework Appendix*.

Beyond the Cost-Benefit Ratio

Under normal USACE policy, for projects which produce both National Economic Development (NED) benefits and National Ecosystem Restoration (NER) benefits, the plan selected for recommendation is the one that maximizes the sum of net NED and NER benefits. Exceptions to the normal policy for selecting the combined NED/NER plan may be granted when there are overriding reasons for recommending another plan based on other Federal, State, local, and international concerns. Since the authority directed USACE to develop plans exclusive of normal policy, this exception has been applied to LACPR.

Hurricanes Katrina and Rita clearly highlighted that maximizing excess NED benefits (i.e. only implementing projects with a cost-benefit ratio greater than one) did not result in the level of risk reduction desired by the Nation. Therefore, the LACPR effort includes a comprehensive planning framework that assesses both economic and non-economic assets at risk. This framework follows the established planning principles but is not solely based on the traditional NED or NER analysis. The term “risk-informed decision framework” has been used to describe this framework which incorporates risk and decision science methods into the planning process. These methods incorporate the consequences of possible events, the associated uncertainty of the metric’s performance in scoring plans, the uncertainties of planning assumptions, and the contribution of stakeholder input.

Multi-Criteria Decision Analysis (MCDA) is the approach that the LACPR effort is employing to support the quantitative comparison and ranking of alternative plans. MCDA provides the means to weigh a plan’s performance with respect to planning objectives and the relative value stakeholders and decision makers place upon those objectives.

Incorporating Multi-Criteria Decision Analysis into USACE Planning

The MCDA translates all metric outputs into a performance score for each evaluated plan. A plan’s performance score is generated by combination of a metric’s input data with associated weighting functions developed from stakeholder and decision maker values. The scores are then compared to the full range of a planning unit’s alternative plans, ranking them by the degree to which they satisfy the objectives.

An Illustrative Example Application of MCDA

The following example is a decision problem that is common to the experience of most people. The example illustrates how the MCDA process can help in reaching a decision that involves multiple interests and objectives.

A family car purchase is a major decision given the costs involved and the family's reliance on the benefits it provides. The family, the decision makers in this example, must first decide what characteristics the family car must have to meet their needs. In other words, the members of the family must decide on a set of objectives that will govern the decision they will make. In this hypothetical example, the family deliberates on the process facing them and selects the specific set of metrics presented in **Table 7-1** to represent their objectives and interests relative to the car purchase. The array of metrics include those that evaluate quantitative factors such as purchase, operation, and repair/maintenance costs along with qualitative factors like comfort, style, and safety. MCDA will then be used to create a total score that integrates all the metric data for each car purchase option. This total score will represent the degree to which each option satisfies the family's objectives, represented by the metrics.

The family's interests are in minimizing the purchase cost and repair/maintenance costs while maximizing resale value, fuel efficiency, space, style and comfort, and safety. However, the data assembled in **Table 7-1** shows that no one car option has the most desirable value for each metric.

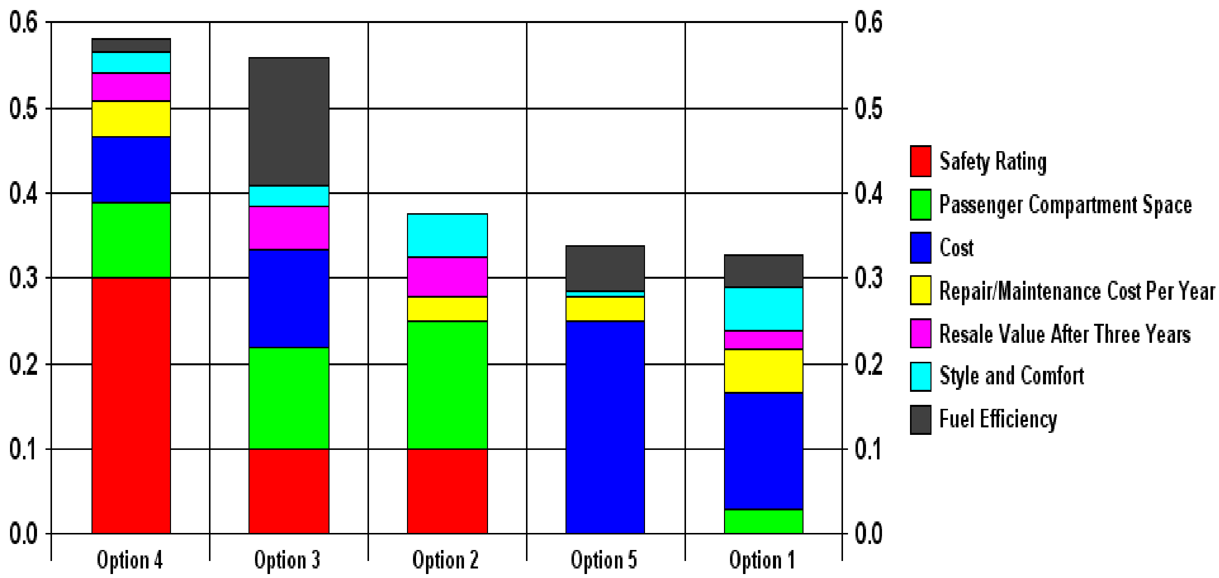
Table 7-1. MCDA data applied to car purchase example.

Metric (Weight)	Units	Car Options				
		Option 1	Option 2	Option 3	Option 4	Option 5
Cost (25)	Dollars	27,000	45,000	30,000	35,000	12,000
Resale Value After Three Years (5)	% of Original Value	44	56	57	49	33
Repair/Maintenance Cost Per Year (5)	Dollars	100	500	1,000	250	500
Fuel Efficiency (15)	Miles per Gallon	30	25	45	27	32
Passenger Compartment Space (15)	Cubic Feet	150	170	165	160	145
Style and Comfort (5)	Qualitative	Finest	Finest	Average	Average	Poor
Safety Rating (30)	NHTSA Safety Rating	2	3	3	5	2

The family's objectives and the metric data reveal the existence of a number of potential trade-offs that are relevant to the decision, whereby getting more satisfaction relative to one attribute (e.g., lower cost for option 5) comes at the expense of another attribute (e.g., less passenger compartment space in option 5). Integrating across metrics to develop a total score requires that the family decide how important each objective/metric is to them in view of the decision they are making. The family's values concerning these objectives will be expressed in the form of weighting factors that will be applied to each metric. In this example, the family allocated weight across the metrics, where the number in parentheses next to each metric's name represents the proportion of total weight (100%) that they wish to allocate to each metric. As shown, the family decided that vehicle safety rating would be assigned a weight of 30%, purchase cost 25% and so on, such that the total weight allocated across all the metrics adds up to 100%.

Through the MCDA a total score is computed for each option using the quantitative and qualitative (e.g., finest, average, poor for style and comfort) information collected for each metric and the weighting values. The results of this calculation are shown in **Figure 7-1** below, which shows a ranking of the options based on each option's total score. The score yields a number between 0 and 1. As score values increase it means that the degree to which the family's objectives and values are being met is increasing. In this example, option 4 received the highest score followed by options 3, 2, 5, and 1. **Figure 7-1** also shows the contribution that each metric, combined with its associated weight, is making to each option's score. The relative contribution each metric is making is represented by the height of the space within the bar corresponding to each metric's color.

Figure 7-1. MCDA as applied to purchase of a car – weighting example 1.

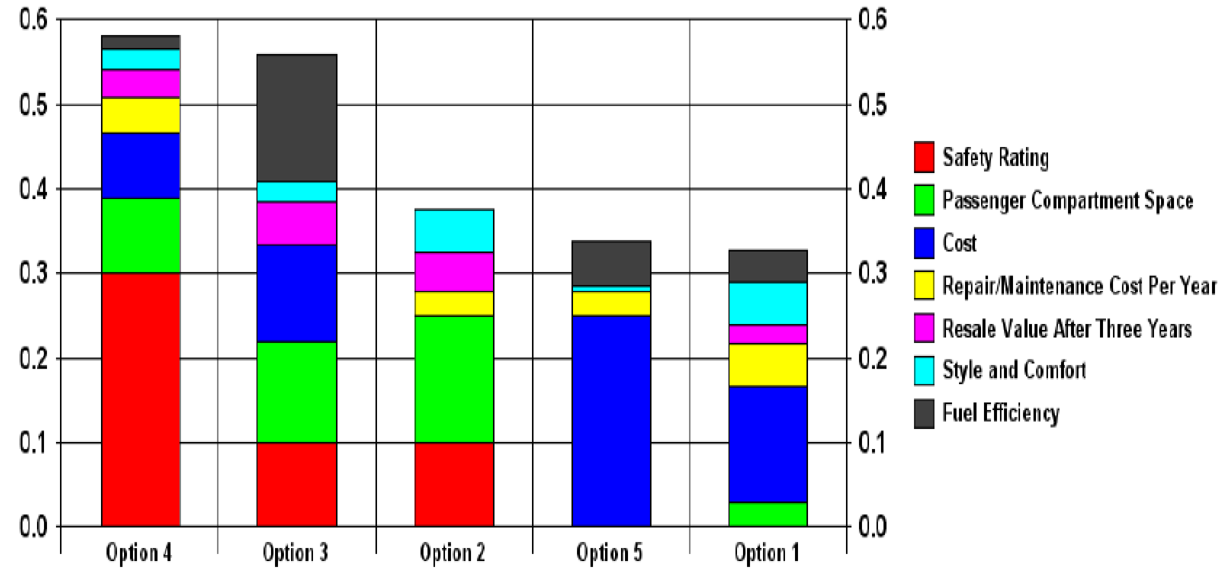


One of the benefits of using MCDA for such multi-objective decision problems is that the quantitative methods employed provide insight into how objectives and weighting values contribute to decisions; such information supports the dialogue and deliberation required to make decisions. One of the decisions that the analysis results could support to this point is for the family to decide to concentrate its attention on options 4 and 3, as these two options are clearly scoring higher than options 2, 5, and 1. The family may decide that they need to collect more information about options 3 and 4 to help them distinguish these options from each other, given the similarity in their overall scores.

MCDA also provides an opportunity to explore a ranking's robustness, i.e., how sensitive the ranking of options may be to changes in metric value inputs or the distribution of weight among the metrics. **Figure 7-2** shows a specific example of the ranking of options' sensitivity to changes in weight assigned to the cost and safety metrics. The results in **Figure 7-2** show the option ranking, and the contribution of each metric to that ranking, for the case where the weight associated with the cost metric was increased from 25% to 30% and the weight associated with the safety metric was reduced from 30% to 25%. Comparing the results in **Figure 7-2** with the results in **Figure 7-1** illustrates how sensitive the ranking is to these changes in weight. Options 4 and 3 remain the top-ranked options, but their relative order has changed. Likewise, the relative order of the remaining options has changed, but options 5, 2, and 1 are still ranked at a lower position compared to options 3 and 4. It should be noted here that similar sensitivity analyses can be performed to explore the implications of uncertainties associated with the metric data as well.

This simple example illustrates some of the basic features of MCDA and its role in facilitating the deliberation necessary to resolve multi-objective decision problems.

Figure 7-2. MCDA as applied to purchase of a car – weighting example 2.



Summary of the LACPR Metrics

In the car buying example above, seven metrics (fuel efficiency, cost, safety rating, style and comfort, etc.) provided quantitative measurements of a car's performance for a range of consumer objectives. Similarly, the 14 LACPR metrics previously described in this report provide the measurement of a plan's performance against the basic objectives identified for LACPR. The LACPR metrics, which are used to evaluate and compare plans, have been summarized in **Table 7-2** below.

Table 7-2. Summary of LACPR metrics by planning account.

Metric No.	Account	Metric	A high weighting for this metric indicates a preference for alternatives that:
1	NED	Residual Damages	Minimize residual damages.
2	NED	Life-cycle Cost	Minimize life-cycle cost.
3	NED	Construction Time	Minimize construction time.
4	EQ	Spatial Integrity	Maximize spatial integrity or sustain the coastal landscape.
5	EQ	Direct Wetland Impacts	Minimize direct wetland loss associated with levee construction.
6	EQ	Wetlands Created and/or Protected	Maximize wetland creation and/or protection.
7	EQ	Indirect Impacts	Minimize indirect impacts associated with levee construction.
8	EQ	Historic Properties Protected	Maximize the number of historic properties protected.
9	EQ	Archaeological Sites Protected	Maximize the number of archaeological sites protected.
10	RED	Gross Regional Output Impacted	Minimize the impacts to regional business output.
11	RED	Employment Impacted	Minimize the impacts to regional employment.
12	RED	People’s Earned Income Impacted	Minimize the impacts to regional earned income.
13	OSE	Residual Population Impacted	Minimize the number of people who experience flooding.
14	OSE	Historic Districts Protected	Maximize the number of historic districts protected.

Weighting of Metrics and Stakeholder Value Identification

A key component of the MCDA process is determining relative weight, or value, for each metric. Eliciting weights from team members, technical experts, stakeholders and other interested and affected parties provides the means to incorporate multiple viewpoints into the comparison of plans and objectives. The MCDA process also provides the means for exploring the implications of variation among stakeholders in these values on plan scoring and ranking, thus facilitating deliberative decision making. MCDA results provide a basis for examining and discussing differences and similarities, both in the expressed values and their ultimate effect on the comparison and ranking of plans.

In October 2007, the LACPR team held a series of interactive workshops with Federal and State agency representatives and other stakeholders to obtain direct weighting values for the metrics relative to the interests and objectives of these individuals and groups. At this initial stage the method for weights does not allow the planning team to fully gauge the value preferences of the stakeholders. This analysis will be more effectively accomplished in the next iteration of engaging stakeholders when they are able see these initial results and more fully understand the underlying data and tradeoffs. Gathering these weights from a group of stakeholders served the following purposes:

- To expose the stakeholders to the MCDA process,

- To develop a set of data for use in an example ranking of plans, and
- To explore the possible variance in metric weight values.

Over 80 agencies and stakeholders participated in the weighting of metrics as follows:

- 7th Ward Gravity Drainage District
- Abbeville Harbor and Terminal
- Amite River Basin Commission
- Atchafalaya River Coalition
- Avery Island, Inc.
- Barataria-Terrebonne National Estuary Program
- Biloxi Marsh Lands Corp.-Lake Eugenie Land Development
- C.S. Gaidry, Inc.
- Calcasieu Parish Police Jury
- Chief Administrative Officer, St. Mary Parish Gov't
- Citizens for a Safer Jefferson
- City of Kaplan
- City of New Orleans
- CLEAR at Louisiana State University
- Coalition to Restore Coastal Louisiana
- Congressman Charles W. Boustany
- ConocoPhillips
- Continental Land and Fur Company
- Ducks Unlimited, Inc.
- Federal Highway Administration
- Federal Emergency Management Agency
- Fish and Wildlife Service
- Gray Law Firm/Tower Land Company, LLC
- Greater Lafourche Port Commission
- Harry Bourg Corporation/Land Owner
- Jefferson Parish Environmental Department
- LA 1 Coalition
- Lafourche Parish Farm Bureau
- Lake Pontchartrain Basin Foundation
- Louisiana Department of Natural Resources
- Louisiana Department of Transportation and Development
- Louisiana Department of Wildlife and Fisheries
- Louisiana Farm Bureau
- Louisiana Wildlife Federation
- M.O. Miller Estate
- Miami Corporation
- Minerals Management Service
- National Audubon Society
- National Marine Fisheries Service
- National Weather Service
- National Wildlife Federation
- Natural Resources Conservation Service
- The North American Land Co./Sweet Lake Land and Oil
- North Lafourche Conservation Levee and Drainage District
- Orleans Audubon Society
- Orleans Levee District
- Plaquemines Parish Government
- Port of Lake Charles
- Providence Engineering
- Restore or Retreat-Governor's Coastal Commission
- Senator Landrieu's Office
- Senator Vitter's Office
- Shell Oil Company
- St. Bernard Parish Coastal Zone Advisory Commission
- St. Bernard Parish
- St. Mary Industrial Group
- St. Tammany Parish
- Stream Companies
- Sweet Lake Land and Oil
- Teche Vermilion Fresh Water District
- Terrebonne Levee and Conservation District
- Terrebonne Parish
- Terrebonne Parish Coastal Zone Committee
- Terrebonne Parish School Board
- Town of Berinda
- Town of Erath
- United Houma Nation
- University of New Orleans/Civil Engineering
- University of New Orleans/Pontchartrain Institute for Environmental Sciences
- U.S. Environmental Protection Agency
- U.S. Geological Survey
- Vermilion Cattlemen Association
- Vermilion Parish Coastal Advisory
- Vermilion Parish DEP
- Vermilion Parish Drainage District 2
- Vermilion Parish Office of Homeland Security and Emergency Preparedness
- Waist Deep Duck, LLC

Agency and stakeholder groups weighted the metrics based on the metric descriptions only, absent any information about metric values or plan performance. The planning team selected a subset of this data, which represents a range of governmental agency values, and is using that input for the purpose of illustrating the use of value and weight information in the process. A statistical analysis identified four similar preference patterns, or clusters of common values derived from a subset of the data (Clusters A, B, C and D).

Table 7-3 presents the ranges of metric weights identified from the agencies and stakeholders as compared to four example clusters identified in the selected data subset.

Table 7-3. Range and clusters of initial agency and stakeholder weights for each metric.

Metric	Description	Account	Range		Sample Data Cluster			
			Low	High	A	B	C	D
1	Residual Damages	NED	0.04	0.21	0.05	0.02	0.18	0.10
2	Life-cycle Cost	NED	0.02	0.12	0.09	0.05	0.16	0.05
3	Construction Time	NED	0.04	0.16	0.07	0.04	0.06	0.05
4	Spatial Integrity	EQ	0.05	0.19	0.11	0.11	0.05	0.06
5	Direct Wetland Impacts	EQ	0.05	0.15	0.16	0.2	0.06	0.08
6	Wetlands Created and/or Protected	EQ	0.08	0.32	0.20	0.29	0.05	0.15
7	Indirect Impacts	EQ	0.04	0.14	0.12	0.17	0.05	0.09
8	Historic Properties Protected	EQ	0.01	0.04	0.02	0.01	0.02	0.06
9	Archaeological Sites Protected	EQ	0.02	0.04	0.02	0.01	0.09	0.03
10	Gross Regional Output Impacted	RED	0.02	0.20	0.04	0.01	0.06	0.05
11	Employment Impacted	RED	0.01	0.10	0.04	0.02	0.07	0.06
12	People’s Earned Income Impacted	RED	0.01	0.14	0.03	0.02	0.05	0.06
13	Residual Population Impacted	OSE	0.02	0.18	0.04	0.04	0.08	0.12
14	Historic Districts Protected	OSE	0.01	0.04	0.02	0.02	0.02	0.05

Example MCDA Plan Rankings

The complete MCDA incorporating all metrics weighted by stakeholder values with their understanding of metric value ranges and their effects on plans will not be performed until early 2008. The rankings presented here are not an attempt to select a plan but to describe the status of the process in comparing and ranking plans. The rankings presented below are only a first step to be used as an example. Additional iterative stakeholder engagement will be necessary before a recommendation is developed.

Comparing these different rankings illustrates the plan ranking sensitivity to different sets of decision criteria. Plans that rank high using different ranking criteria could aid in identifying plans that would be broadly supported among stakeholders and decision makers. Because MCDA provides a ranking that integrates plan objectives with stakeholder values, the resulting assessment of relative performance provides a more comprehensive decision process.

MCDA allows varying values for each of the performance metrics as previously discussed. The information presented in **Table 7-4 through Table 7-13** below shows the effect of the application of each of the four clusters of common values identified in the sample data set for each Planning Unit. In these tables plans that are found to be top performers regardless of the weight applied are highlighted. In the final MCDA analysis plans such as this would be generally more acceptable across the range of stakeholder interests in addition to effectively providing the outputs being valued.

A second table is presented for each planning unit that displays how plans might rank if more limited criteria were employed to gauge relative performance. The plans highlighted in these tables reflect the plans that also were highlighted in all four of the MCDA weighted rankings. This illustrates the relative effectiveness of the MCDA process in identifying plans that can meet both a broad or focused criteria. For purposes of general comparison, the rankings presented list the ten best performing plans in meeting the applied ranking criteria.

The three additional non-MCDA ranking approaches being presented are defined below.

- **Plan Ranking Based on Cost Efficient Damage Reduction** - This plan ranking approach focuses solely on efficiency in achieving relative economic risk reduction, benefiting decision makers responsible for managing fiscal resources at a National level. However, it minimizes or ignores other major output categories such as regional economy, environmental quality and stability, and local social values.
- **Plan Ranking Based on Minimizing Environmental Impacts** - This plan ranking approach compares values developed from the residual damages, direct wetland impacts and indirect impacts metrics. Since coastal and nonstructural alternatives typically present no direct or indirect impacts they rank highest in this type of ranking. Other metrics must be used to differentiate plans.
- **Plan Ranking Based on the "Category 5" Congressional Directive** - This approach ranks only plans that are designed to the 400- or 1000-year risk reduction level, representing a range of "Category 5" storms. This ranking method highlights the plans meeting specific LACPR authorizing language objectives, eliminating those not meeting the criteria, and then further narrowing the list to the least present-value cost.

Planning Unit 1

The following is a guide to the Planning Unit 1 alternative codes in **Tables 7-4 and 7-5**:

- **100, 400, and 1000:** the level of risk reduction, i.e. 100-year, 400-year, and 1000-year.
- **NS:** stand alone nonstructural plan.
- **R1, R2, and R3:** variations on coastal restoration landscapes.
- **C:** "comprehensive" plan defined as a plan that includes coastal restoration, structural measures, and complementary nonstructural measures to fill in where there are no structural measures.
- **LP:** plans with a barrier-weir across The Rigolets and Chef Menteur Pass to reduce surge entering Lake Pontchartrain.
- **HL:** plans that do not include a barrier-weir as described above, but provide risk reduction by raising existing levees.
- **a:** variation that includes an alignment at the confluence of the GIWW and MRGO.
- **b:** variation that includes an alignment at the edge of the Golden Triangle and Lake Borgne.
- **1:** primary alignment. All PU1 primary alternatives include the Lake Pontchartrain and Vicinity levees and upper Plaquemines levees. The primary alignments for 'LP' also include a barrier-weir across the passes of Lake Pontchartrain with a tieback to high ground east of Slidell.

- **2:** primary alignment described above plus Northshore and Westshore levees.
- **3:** primary alignment described above plus Slidell and Westshore levees.

Table 7-4. Comparative MCDA rankings for Planning Unit 1.

Plan Rank	Weight-1A	Weight-1B	Weight-1C	Weight-1D
1	**NS-400**	**NS-400**	**NS-1000**	**NS-1000**
2	**NS-100**	**NS-100**	**NS-400**	**NS-400**
3	**NS-1000**	**NS-1000**	**NS-100**	**NS-100**
4	R1	R1	**C-HL-a-100-3**	**C-HL-a-100-2**
5	R2	R2	**C-HL-a-100-2**	**C-HL-a-100-3**
6	R3	R3	**HL-a-100-2**	C-HL-b-400-3
7	**C-HL-a-100-3**	**C-HL-a-100-3**	**HL-a-100-3**	**HL-a-100-2**
8	**HL-a-100-3**	**HL-a-100-3**	C-LP-a-100-1	**HL-a-100-3**
9	**C-HL-a-100-2**	**C-HL-a-100-2**	C-HL-b-400-3	HL-b-400-3
10	**HL-a-100-2**	**HL-a-100-2**	C-LP-a-100-3	C-LP-a-100-1

Table 7-5. Comparison of alternate ranking methods to MCDA for Planning Unit 1.

Plan Rank	NED Ranking Based on Cost Efficiency	"Cat 5" Ranking Based on Present Value Costs	EQ Ranking Based on EQ Metrics
1	**NS-100**	LP-b-400-1	R1
2	C-LP-a-100-1	LP-b-1000-1	R2
3	**NS-400**	C-LP-b-400-1	R3
4	**NS-1000**	**NS-400**	**NS-100**
5	R1	HL-b-400-3	**NS-400**
6	**C-HL-a-100-3**	LP-b-400-3	**NS-1000**
7	**C-HL-a-100-2**	C-LP-b-1000-1	**HL-a-100-3**
8	R2	C-HL-b-400-3	**C-HL-a-100-3**
9	LP-a-100-1	**NS-1000**	HL-b-400-3
10	C-LP-b-400-1	C-LP-b-400-3	C-HL-b-400-3

Planning Unit 2

The following is a guide to the Planning Unit 2 alternative codes in **Tables 7-6 and 7-7**:

- **100, 400, and 1000:** the level of risk reduction, i.e. 100-year, 400-year, and 1000-year.
- **NS:** stand alone nonstructural plan.
- **R1, R2, and R3:** variations on coastal restoration landscapes.
- **C:** "comprehensive" plan defined as a plan that includes coastal restoration, structural measures, and complementary nonstructural measures to fill in where there are no structural measures.
- **WBI:** west bank interior plan.
- **R:** ridge alignment plan (parallel to ridges along the West Bank of the Mississippi River and Bayou Lafourche.
- **G:** GIWW alignment plan
- **1:** primary alignment. All PU2 primary alignments include West Bank and Vicinity levees with new sector gate and Larose to Golden Meadow levees. Primary alignments for 'R' and 'G' also include Lafitte ring levees.
- **2:** primary alignment described above plus Boutte levee.
- **3:** primary alignment described above plus Boutte and Des Allemands levee.
- **4:** primary alignment described above plus Boutte, Des Allemands, and Bayou Lafourche levees.

Table 7-6. Comparative MCDA rankings for Planning Unit 2.

Plan Rank	Weight-1A	Weight-1B	Weight-1C	Weight-1D
1	**C-R-100-3**	**C-R-100-3**	C-G-100-4	C-R-400-3
2	**C-WBI-100-1**	**C-WBI-100-1**	**C-R-100-3**	C-WBI-400-1
3	WBI-100-1	C-R-100-2	C-WBI-400-1	**C-R-100-3**
4	C-R-100-2	WBI-100-1	C-R-400-3	C-R-100-4
5	C-R-100-4	R-100-2	**C-WBI-100-1**	NS-1000
6	C-WBI-400-1	R-100-3	C-G-100-1	C-R-400-2
7	C-R-400-3	C-R-100-4	NS-100	NS-400
8	NS-100	R-100-4	C-G-400-4	C-R-400-4
9	R-100-2	NS-100	NS-1000	C-G-400-4
10	R-100-3	NS-1000	NS-400	**C-WBI-100-1**

Table 7-7. Comparison of alternate ranking methods to MCDA for Planning Unit 2.

Plan Rank	NED Ranking Based on Cost Efficiency	"Cat 5" Ranking Based on Present Value Costs	EQ Ranking Based on EQ Metrics
1	NS-100	WBI-400-1	R1
2	**C-WBI-100-1**	R-400-2	R2
3	C-G-100-1	C-WBI-400-1	R3
4	R1	R-400-3	NS-100
5	R2	R-400-4	NS-400
6	C-R-100-2	C-R-400-2	NS-1000
7	WBI-100-1	G-400-4	R-100-2
8	**C-R-100-3**	C-R-400-3	C-R-100-2
9	C-G-100-4	NS-400	R-100-3
10	R3	C-R-400-4	**C-R-100-3**

Planning Unit 3a

The following is a guide to the Planning Unit 3a alternative codes in **Tables 7-8 and 7-9**:

- **100, 400, and 1000:** the level of risk reduction, i.e. 100-year, 400-year, and 1000-year.
- **NS:** stand alone nonstructural plan.
- **R1:** coastal restoration landscape.
- **C:** "comprehensive" plan defined as a plan that includes coastal restoration, structural measures, and complementary nonstructural measures to fill in where there are no structural measures.
- **M:** Morganza levee alignment
- **G:** GIWW alignment plan with Morganza levee at 100-year design.
- **1:** Morganza alignment with tieback to high ground west of Morgan City.
- **2:** Morganza alignment with tieback to high ground south of Thibodaux and ring levee around Morgan City.

Table 7-8. Comparative MCDA rankings for Planning Unit 3a.

Plan Rank	Weight-1A	Weight-1B	Weight-1C	Weight-1D
1	**NS-1000**	**NS-1000**	**C-M-100-1**	**C-M-100-1**
2	**NS-400**	**NS-400**	**M-100-1**	**M-100-1**
3	NS-100	NS-100	**C-M-100-2**	**C-M-100-2**
4	R1	R1	**M-100-2**	**M-100-2**
5	**M-100-2**	**M-100-2**	**NS-1000**	C-G-1000-2
6	**C-M-100-2**	**C-M-100-2**	**C-G-400-2**	**NS-1000**
7	**C-M-100-1**	**C-M-100-1**	**NS-400**	**C-G-400-2**
8	**M-100-1**	**M-100-1**	C-G-1000-2	G-1000-2
9	**C-G-400-2**	**C-G-400-2**	**G-400-2**	**NS-400**
10	**G-400-2**	**G-400-2**	G-1000-2	**G-400-2**

Table 7-9. Comparison of alternate ranking methods to MCDA for Planning Unit 3a.

Plan Rank	NED Ranking Based on Cost Efficiency	"Cat 5" Ranking Based on Present Value Costs	EQ Ranking Based on EQ Metrics
1	NS-100	**NS-400**	NS-100
2	**NS-400**	**NS-1000**	**NS-400**
3	**NS-1000**	**C-G-400-2**	**NS-1000**
4	**M-100-2**	C-G-1000-2	R1
5	**C-M-100-1**	**G-400-2**	**M-100-2**
6	**C-M-100-2**	G-1000-2	**C-M-100-2**
7	**M-100-1**		**M-100-1**
8	**C-G-400-2**		**C-M-100-1**
9	C-G-1000-2		**G-400-2**
10	**G-400-2**		**C-G-400-2**

Planning Unit 3b

The following is a guide to the Planning Unit 3b alternative codes in **Tables 7-10 and 7-11**:

- **100, 400, and 1000:** the level of risk reduction, i.e. 100-year, 400-year, and 1000-year.
- **NS:** stand alone nonstructural plan.
- **R1:** coastal restoration landscape.
- **C:** "comprehensive" plan defined as a plan that includes coastal restoration, structural measures, and complementary nonstructural measures to fill in where there are no structural measures.
- **G:** GIWW levee alignment.
- **F:** Franklin to Abbeville alignment (inland of the GIWW).
- **RL:** ring levee alignment.
- **1:** primary alignment (no variations to primary alignments in PU3b).

Table 7-10. Comparative MCDA rankings for Planning Unit 3b.

Plan Rank	Weight-1A	Weight-1B	Weight-1C	Weight-1D
1	**RL-100-1**	**RL-100-1**	**RL-100-1**	**RL-100-1**
2	**RL-400-1**	C-RL-100-1	**RL-400-1**	**RL-400-1**
3	C-RL-100-1	**RL-400-1**	C-G-100-1	F-1000-1
4	NS-1000	NS-1000	**C-F-100-1**	**C-F-100-1**
5	NS-400	NS-400	G-100-1	C-F-400-1
6	**C-F-100-1**	C-RL-400-1	**F-100-1**	**F-100-1**
7	**F-100-1**	**C-F-100-1**	F-1000-1	C-G-100-1
8	C-RL-400-1	**F-100-1**	C-RL-100-1	F-400-1
9	NS-100	NS-100	NS-1000	G-100-1
10	C-F-400-1	R1	NS-400	C-RL-400-1

Table 7-11. Comparison of alternate ranking methods to MCDA for Planning Unit 3b.

Plan Rank	NED Ranking Based on Cost Efficiency	“Cat 5” Ranking Based on Present Value Costs	EQ Ranking Based on EQ Metrics
1	NS-100	NS-400	**RL-100-1**
2	NS-400	NS-1000	C-RL-100-1
3	NS-1000	C-RL-400-1	**RL-400-1**
4	C-RL-100-1	C-F-400-1	C-RL-400-1
5	C-G-100-1	F-400-1	NS-100
6	**C-F-100-1**	**RL-400-1**	NS-400
7	G-100-1	C-F-1000-1	R1
8	**F-100-1**	F-1000-1	NS-1000
9	C-RL-400-1		**F-100-1**
10	**RL-100-1**		**C-F-100-1**

Planning Unit 4

The following is a guide to the Planning Unit 4 alternative codes in **Tables 7-12 and 7-13**:

- **100, 400, and 1000:** the level of risk reduction, i.e. 100-year, 400-year, and 1000-year.
- **NS:** stand alone nonstructural plan.
- **R1:** coastal restoration landscape.
- **C:** "comprehensive" plan defined as a plan that includes coastal restoration, structural measures, and complementary nonstructural measures to fill in where there are no structural measures.
- **G:** GIWW levee alignment.
- **RL:** ring levee alignment.
- **1:** primary alignment. For the 'G' alignments, the primary alignment follows the GIWW across the planning unit boundaries.
- **2:** GIWW alignment with tieback to high ground near Kaplan.
- **3:** GIWW alignment with the levee set at a height of 12 feet.

Table 7-12. Comparative MCDA rankings for Planning Unit 4.

Plan Rank	Weight-1A	Weight-1B	Weight-1C	Weight-1D
1	**NS-1000**	**NS-1000**	**NS-1000**	**NS-1000**
2	**NS-400**	**NS-400**	**C-RL-400-1**	**NS-400**
3	**NS-100**	**NS-100**	**NS-400**	**C-RL-1000-1**
4	**C-RL-400-1**	R1	**C-RL-1000-1**	**NS-100**
5	**C-RL-100-1**	**C-RL-400-1**	**C-RL-100-1**	**C-RL-400-1**
6	**C-RL-1000-1**	**C-RL-100-1**	**NS-100**	**C-RL-100-1**
7	RL-100-1	**C-RL-1000-1**	C-G-1000-3	C-G-100-1
8	R1	RL-100-1	C-G-100-1	C-G-1000-3
9	RL-400-1	RL-400-1	C-G-400-3	C-G-400-3
10	RL-1000-1	RL-1000-1	C-G-100-2	RL-100-1

Table 7-13. Comparison of alternate ranking methods to MCDA for Planning Unit 4.

Plan Rank	NED Ranking Based on Cost Efficiency	"Cat 5" Ranking Based on Present Value Costs	EQ Ranking Based on EQ Metrics
1	**NS-100**	**NS-400**	**NS-100**
2	**NS-400**	**NS-1000**	**NS-400**
3	**NS-1000**	**C-RL-400-1**	**NS-1000**
4	**C-RL-400-1**	**C-RL-1000-1**	R1
5	**C-RL-1000-1**	C-G-400-3	RL-100-1
6	**C-RL-100-1**	C-G-1000-3	**C-RL-100-1**
7	C-G-400-3	G-400-3	RL-400-1
8	C-G-1000-3	RL-1000-1	**C-RL-400-1**
9	C-G-100-2	RL-400-1	RL-1000-1
10	C-G-100-1	G-1000-3	**C-RL-1000-1**

Observations on the Initial MCDA Application

The following sections provide observations on the data and plan performance for the initial multi-criteria decision analysis application.

Data Performance

The potential for various metrics to influence the ranking process to a relatively greater or lesser extent is understood within the MCDA technique. In fact this possibility as been explicitly communicated to the planning team as well as agency and stakeholder participants in the weight elicitation exercise. These variations in effect are generally due to the range of variance in the output of the particular metric produced by the plans evaluated. If the output value of a metric varies greatly from plan to plan it has a high potential to influence the ranking of plans. Conversely if the output value of a particular metric changes very little from plan to plan it will have little influence over the rank order of the plans.

Keeping in mind that the metric outputs represent varying measures of specific performance on which the stakeholder are placing relative value, the relative weight/value placed on each metric may only have a significant effect on the relative ranking of plans if the metric outputs have this high variation. However, if the metric outputs have very little variation even an extremely high weight/value for that particular area of performance may not cause that metric value to influence the relative rank order of plans. Conversely the application of a relatively low weight/value to a metric with a high variation in its output will tend to neutralize its ability to have any effect on the relative rank order of plans. It might also be observed that the higher the precision of the measurement of the metric output the more likely it is that the output values will show a significant variation. This is not, however, always the case. For example the output value for Indirect impacts is a relatively narrow qualitative range, however since the performance tendencies of the plans are at the extremes for this metric, and the value weight is high, the relative effect on plan ranking is pronounced.

Performance of Nonstructural vs. Structural Plans

The single most apparent observation that can be made on the various alternative plans from these example rankings is that the nonstructural/coastal plan combination performs uniformly well regardless of the approach employed. This performance is a result of the relatively high level of risk reduction that they provide, resulting in cost efficiency consistent across all design levels of the nonstructural plans.

The analytic assumption for these plans is that 100 percent of those structures identified for some nonstructural action will undergo those actions. The accepted approach for implementation of nonstructural actions, however, calls for voluntary participation. As a result, the level of performance of these nonstructural plans will be sensitive to the degree of participation in the program and sensitivity analyses need to be run for lower levels of participation.

In applying the more narrowly focused ranking approach of cost efficiency using NED criteria, incremental results based on participation would likely show a continuing efficiency of plans regardless of varying level. However, in applying the MCDA approach for ranking, a critical threshold for participation is possible. At that threshold, a reduced level of output would cause plans to diminish in rank due to their inability to provide adequate output relative to values indicated by the applied weight.

The potential for the actual performance level of the nonstructural plans to vary from what was estimated based on the initial assumptions will not affect their relative efficiency in supplying residual risk reduction. In the current evaluation, reduced participation generally causes the cost of the plan to decrease along with the level of residual risk. Within the context of the MCDA analysis, however, where all outputs are being gauged, value weighted, and combined into a single score, rather than compared to one another to produce a ratio, reducing a plan's residual risk can potentially cause those plans to score more poorly relative to other plans.

Conversely, the evaluation of plans involving structural measures may be unfairly scored due to limitations in detail of interior flood modeling for the LACPR effort. For example, a single stage storage relationship was used to predict flood levels in each of the large basins within the New Orleans area. This stage storage approach effectively fills the lowest areas first and does not capture the dynamic effects needed for temporal and areal flood predictions. Therefore, when stage storage water level predictions are used to estimate residual damages, the precision of the estimate necessarily suffers when compared to a more rigorous modeling approach.

Additional analyses and sensitivities need to be and will be conducted to understand the potential problem in the evaluation and the impact it may have on report findings. The damages associated with the 10-year rainfall event may be overstated because of several cumulative effects resulting from not only the simplification used in developing and applying stage storage relationships, but also in the development of the stage damage relationships themselves. The team will perform sensitivity analyses for selected planning subunits to assess assumptions and process used to calculate damages. More analysis may be required at the next level of investigation to address interior drainage problems and possible solutions.

Performance of Nonstructural vs. Comprehensive Plans

The comprehensive plans (at 100-year, 400-year, and 1000-year) have more residual damages than the comparable design coastal/nonstructural alternative, because the combined plans include areas protected only by structural measures that still result in high residual damages associated with the 10-year event (these damages are significantly reduced in the coastal/nonstructural alternatives). The comprehensive plans were built off the structural plans, adding nonstructural components to unprotected areas thereby providing a uniform system protection at the design level being addressed. To simplify evaluations at this stage of the effort, further reduction of risk behind proposed design levees for structural alternatives by implementation of additional nonstructural measures, to further increase level of protection, has not been done.

Section 8. Example LACPR Program Management

The ultimate success of LACPR will be a reflection of its implementation over a long period. Simply stated, hard work lies ahead in terms of significantly reducing risk to populated areas in Louisiana and restoring the Louisiana coastal areas. A well-coordinated strategy, based on the USACE’s Actions for Change which recognizes the need for a comprehensive systems approach to coastal protection and restoration, risk-informed decision making, communication of risk to the public, and technical and professional expertise, will facilitate success and ensure that all LACPR efforts are fully coordinated with other coastal protection and restoration projects in the State of Louisiana, including the State’s Master Plan in addition to the Mississippi Coastal Improvements Program (MsCIP).

A project of this scope could be executed in a number of ways. The magnitude of the effort involved in the LACPR implementation does not lend itself to the traditional USACE methodology for completing water resource projects. The difficulty is due to the necessity to integrate many related features with each other, as well as with the components of numerous ongoing Federal, State, and local efforts. The need for an intense, innovative, transparent decision-making process is essential to achieve the goals and objectives within a reasonable timeframe. In addition, implementation of each component or group of components within a project will need to be linked to the overall system plan in order to meet the goals on schedule.

The following discussion is intended to characterize the key principles of the USACE’s Actions for Change and to provide some construct of the implementation and adaptive management process needs. It is intended to elicit conversation and to evoke ideas regarding the most effective way to implement LACPR and should be considered a living document, intended to change as needed.

Implementation Principles

The USACE established a set of basic principles for this implementation plan. These guidelines include management strategies for ensuring that the plan is implemented in a manner consistent with the goals and objectives of the coastal protection and restoration. The following principles are discussed in detail in the following sub-sections:

- Utilize Interdisciplinary and Interagency Teams
- Incorporate Outreach and Public Involvement
- Maintain Comprehensive System Focus
- Integrate Ongoing and Future Projects and Programs
- Recognize and Reduce Uncertainties
- Incorporate Adaptive Management Processes
- Ensure Consistency between Programs
- Develop and Refine Models and Tools
- Conduct Peer Review

Utilize Interdisciplinary and Interagency Teams

Accomplishment of LACPR is primarily the responsibility of the USACE, New Orleans District, and a non-Federal cost sharing partner. The LACPR effort has been an open, collaborative process involving Federal and State agencies, and local governments. This multi-agency approach has been used to staff the LACPR team and is essential to facilitate the flow of needed information among agencies, address the complexity of the issues, utilization of skills of specialists in other agencies, and to achieve approval and ownership by the key public agency stakeholders.

The LACPR interagency team approach would continue throughout the implementation period to review, evaluate, and adaptively manage the design, construction, monitoring, and implementation of individual LACPR projects.

Incorporate Outreach and Public Involvement

Public involvement is a critical component in the LACPR evaluation process and the development of the comprehensive plan. Full documentation and discussion of public involvement and outreach efforts are included in the *Stakeholder Appendix* and the *Risk-Informed Decision Framework Appendix*. The extensive public participation and input thus far will be a key component in generating a coastwide vision for protection and restoration efforts.

Throughout public participation efforts in the LACPR evaluation process, the team has sought input from individuals, private entities, local governments, academia, and state and federal agencies, in addition to other stakeholders such as environmental, navigation, commercial fishing, recreation, agricultural, and oil and gas interests. Meetings are held throughout the coastal region. Furthermore, the team informs the public using web sites, print and broadcast media, and radio interviews, as well as e-mail communications, newsletters and fact sheets. These activities must continue throughout the LACPR implementation.

Maintain a Comprehensive System Focus

Developing a comprehensive and integrated system for coastal protection and restoration requires a process, as well as a product. Here, the system is defined as a group of structures, policies, plans, and practices that interact in an organized fashion to serve a common purpose. A system is created when all the components, taken together, form a functional unit. Building a system requires that components behave or perform in complementary ways that produce cumulative outputs to achieve a stated purpose. All components must enhance the overall performance of the system and are formulated with the system in mind; scaling and timing must complement or increase overall system outputs. Components are defined by their expected interactions and dependencies. The outputs of one component are the inputs of another. The system’s success depends on the reliable performance of each of its components.

Systems rarely function in isolation; therefore, evaluation of each LACPR project will cover each individual function and appraise its contribution to the comprehensive system performance. An integrated system fits seamlessly into a larger context or framework without detracting from or degrading the larger context.

For example, wetlands creation may protect against more frequent, less severe storms or support the integrity of other storm protection features during more severe events. However, the created wetlands should also contribute ecosystem outputs in order to be of value across purposes. The same is true for navigable flood gates. Gate operation should not impede navigation except during storm events when protection takes priority. When a hurricane and storm damage reduction system functions across multiple purposes, this constitutes a form of horizontal integration. At times, project purposes will compete for priority. Knowing the tradeoffs necessary to meet multiple purposes is necessary for horizontal integration.

Vertical system integration occurs when it complements other activities, plans, or programs within the USACE, other Federal agencies or state and local agencies and authorities. A comprehensive system will encompass other efforts for protection, reconstruction and recovery. Achieving vertical integration requires an understanding of the purposes and perspectives of other agencies and how those agencies interact so that decisions can be made regarding this interrelationship.

Achieving compatibility with other Federal, State, and local agencies' goals might require acknowledgement of tradeoffs or setting of priorities. For example, the goal of the USACE's Task Force Hope is to provide a reliable hurricane and storm damage reduction system for the residents and assets of New Orleans by 2011. However, other Federal, State, and local agencies are working to assure a timely economic recovery to areas devastated by Hurricane Katrina. In order to accomplish both goals, a method of risk reduction might be uniformly applied throughout the area, knowing that some areas of high population concentration will be treated similarly to areas that have been decimated by Hurricane Katrina. Alternately, decisions could be made to stage construction so that risk reduction to the resident population is given priority with projects to follow that support recovery. Integration of the flood and storm risk reduction system requires that all parties involved understand the strategy for system completion so that projects can be coordinated and expectations managed.

The components of a system may be quite diverse but all must contribute to a common purpose. Providing risk reduction from floods and storms can take many forms and different governing authorities and entities participate at different levels. Federal, State and local agencies, along with private interests, will need to take responsibility for all actions and construction of physical features designed for the safety of the community.

Interior laterals, canals and pumps drain the city when rainfall occurs and are maintained and operated by local community authorities. Riverbank levees channel Mississippi River floods through the city; floodwalls, levees, flood gates, and closures hold back storm surge. These structures are built by local entities and the Federal government and are maintained locally. The National Flood Insurance Program, as provided by FEMA and enforced by local communities, provides insurance coverage to policyholders in the event of flooding. Local communities and State agencies provide temporary evacuation and shelter from storm or flood events. Local residents take precautions and measures to reduce their susceptibility to floods.

Building and assuring a comprehensive risk reduction system involves using all these components as necessary to address the system's purpose at all levels of government, including local interests. No single entity has authority to implement all these projects and activities. However, before a system can be fully integrated, a means should be devised whereby individual agency and community contributions to the comprehensive system can be evaluated and decisions made with regard to recognized deficiencies.

Integrate Ongoing and Future Projects and Programs

The comprehensive nature of the plans proposed by the LACPR report requires understanding the impacts of these proposals to insure consistency across project purposes and stakeholder needs. Numerous existing and proposed Federal projects address flood control, navigation, hurricane and storm damage risk reduction, and coastal restoration. Further, the State of Louisiana, other Federal agencies, and local governments have projects that impact the coastal landscape. All of these projects have various purposes, authorities, sources of funds, and construction schedules. This presents a major challenge to the integration of plans into a coherent coastal protection and restoration vision.

Of primary importance is how existing and proposed hurricane and storm damage risk reduction projects integrate with the LACPR efforts. The following is a list (**Table 8-1**) of those projects and a description of measures underway to assure integration of these efforts.

Table 8-1. Ongoing projects' integration into LACPR.

Existing Project	Purpose	LACPR Planning Assumptions	Integration with LACPR
Lake Pontchartrain and Vicinity, LA.	Structural risk reduction 100-year frequency for St. Charles, Jefferson, Orleans and St. Bernard Parishes	Project is completed and maintained in accordance with design frequency	Incorporate project into LACPR
Lake Pontchartrain West Shore	Feasibility report for St. John the Baptist Parish adjacent to Lake Pontchartrain	Using post-Katrina design criteria to develop plans and costs	Feasibility report and LACPR being developed concurrently for best opportunity for project authorization
West Bank and Vicinity, LA	Completion of 100-year frequency risk reduction in Jefferson, Orleans and Plaquemines Parishes	Project is completed and maintained in accordance with design frequency	Incorporate project into LACPR
Donaldsonville to the Gulf	Draft feasibility report due December 2008	Using post-Katrina design criteria to develop plans and costs	Feasibility report and LACPR being developed concurrently for best opportunity for project authorization
Larose to Golden Meadow, LA	Structural risk reduction 100-year frequency for project area	Using post-Katrina design criteria to develop plans and costs	Modeling efforts and alternatives are the same for project and LACPR
Morganza to the Gulf	Structural risk reduction 100-year frequency for project area, plus coastal restoration, non-structural and additional levee alignments in conjunction with project plan	Using post-Katrina ADCIRC modeling for 100-year wave heights and periods	To be modeled as part of the comprehensive system for the whole state
Southwest	Feasibility study to be initiated Spring, 2008	Using post-Katrina ADCIRC modeling for	Feasibility report and LACPR being developed

Existing Project	Purpose	LACPR Planning Assumptions	Integration with LACPR
Coastal, LA		100-year wave heights and periods	concurrently for best opportunity for project authorization
Southeast Louisiana Urban Flood Control	Generally provides for 10-year frequency rainfall protection	All authorized work in place	Additional storm-proofing considered as base condition for LACPR
Louisiana Coastal Areas (LCA)	Two main study efforts: Beneficial Use of Dredged Materials, Barataria Basin Barrier Shoreline Restoration – both initiated before LACPR and State Master Plan	Studies underway; Chief's Report signed Jan. 2005 -- Using post-Katrina ADCIRC modeling for 100-year wave heights and periods	Several individual LCA projects overlap LACPR, some of which will be incorporated consistent with the requirements for development of the comprehensive restoration plan directed in WRDA 2008 language
Coastal Wetlands Planning, Protection and Restoration Act (CWPPRA)	Signed in 1990, act authorizes multi-agency committee to select wetland restoration projects in Louisiana	As of September 2007, 143 projects approved, 74 completed, 17 under construction	Some planning is consistent with and supports LCA

Recognize and Reduce Uncertainties

The LACPR technical evaluation builds upon the best available science and engineering knowledge. While previous research efforts have contributed to a strong understanding of the human and natural processes affecting the Louisiana coastal area ecosystems, scientific and technical uncertainties remain. Further, some ongoing decisions may be best addressed as unknowns for now. Developing a strategy to attempt to reduce the risk arising from these uncertainties is necessary.

Numerous types of uncertainties should be addressed to support and improve LACPR efforts. Each uncertainty requires a different resolution strategy based on the effects of the uncertainty on the program, degree of uncertainty, cost of addressing the uncertainty, and the importance of reducing the uncertainty. Different strategies for resolving uncertainties may include focused research projects monitoring existing projects, natural conditions or demonstration projects. Uncertainties may be related to the science, engineering, modeling, socio-economic impacts, implementation, technical methodology, resource constraints, cost, or effectiveness of restoration and protection measures. Uncertainties may also be related to development and refinement of forecasting tools. An uncertainty is considered critical if its resolution is vital to advancing the planning and implementation of LACPR in the near term.

An explicit adaptive management strategy can address these uncertainties to better achieve system objectives. Adaptive management recognizes that knowledge about these future conditions is uncertain. The aim of such a strategy is to find a way to achieve the objective as quickly as possible while avoiding inadvertent mistakes that could lead to unsatisfactory results. Additionally, investigations to further reduce the scientific and technical uncertainties and to enhance the likelihood that restoration and protection projects will successfully meet project goals is necessary during LACPR implementation.

Specific studies will be needed to provide additional detailed design of specific components within LACPR. These studies could potentially include additional or revised ecosystem targets, flood impacts, ecological effects and data collection. Also, new technologies will likely emerge during the implementation process, offering the possibility of improving the LACPR outputs while reducing costs. The implementation process must allow flexibility to consider and include new technologies as they emerge.

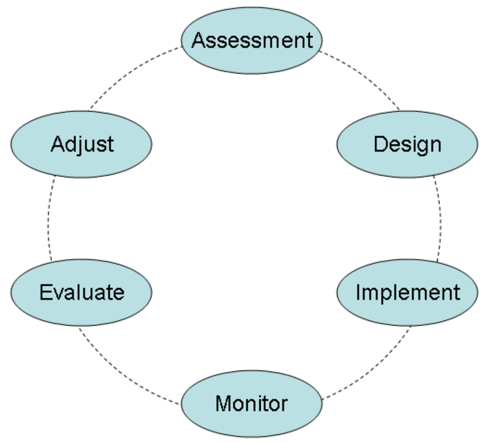
Incorporate Adaptive Management Processes

Resulting from potential changes in social, political, economic, engineering, and environmental conditions, an adaptive management framework to guide program and project management is needed. Adaptive management is a “learning by doing” management approach which promotes flexible decision making that can be adjusted in the face of uncertainties as outcomes from management actions and other events become better understood (National Academy of Sciences 2004). It is used to address the uncertainties that can impede successful implementation of large scale projects such as those contained within LACPR. In adaptive management, a structured process is used so that the “learning by doing” is not simply a “trial and error” process (Walters, 1986). Although most commonly used to resolve ecosystem issues, adaptive management is equally useful in resolving engineering, policy, socioeconomic issues and interactions, and other processes by reducing uncertainties and improving understanding in these areas and their interrelationships.

Additionally, adaptive management is an action-oriented process that can be used to advance projects otherwise stuck in a gridlock of competing predictions of what will or will not happen if certain actions are undertaken. Properly applied, adaptive management can accelerate overall implementation and increase the potential for success.

The basic elements of an adaptive management process are: (1) Assess; (2) Design; (3) Implement; (4) Monitor; (5) Evaluate; and (6) Adjust (**Figure 8-1**). In practice, adaptive management is to be implemented not in a linear sequence, but in an iterative way that ends up repeating steps based on improved knowledge:

Figure 8-1. Components of Adaptive Management: One iteration of the learning wheel.



Source: Nyberg, B. 1999.

Assess: Develop a shared understanding of key social-economic-engineering-ecological interrelationships and associated problems and opportunities. This requires integrating existing interdisciplinary experience and scientific information to clearly characterize the management problem and restoration goals, deciding on indicators to be monitored and used to determine whether future actions achieve objectives, identifying key knowledge gaps (uncertainties or unanswered questions), and developing a range of hypotheses that characterize opinions on how indicators might be affected by alternative actions. Dynamic models are often used to make predictions regarding impacts of alternative policies.

Design: Design management actions as experiments that address not only biophysical criteria and uncertainties, but also social and institutional unknowns as well. Information from the assessment process will be used to design the experiments that will test hypotheses regarding critical uncertainties.

Implement: Put hypotheses and assumptions at risk by testing them in the real world. If mid-course corrections from the design are necessary for unforeseen reasons, it will be critical to openly acknowledge shortcomings and clearly document those deviations to provide opportunities for learning from mistakes.

Monitor: Examine feedback from performance measures and indicators (defined in the assessment phase) to assess “on the ground” outcomes at both the project specific and ecosystem level.

Evaluate: Evaluate options for future actions based on monitoring results.

Adjust: Modify policies, projects or experiments based on what was learned, attempting to keep options open for the future.

The LACPR strategy is to incorporate adaptive management across all components of the LACPR plans in order to improve the pace of learning about restoration, construction, or management of complex systems, while incorporating an acknowledgement that there are uncertainties in the response of systems to these activities. Using a comprehensive systems approach while employing adaptive management will ensure collaborative engagement among stakeholders for program management, project design, construction, and operation and maintenance, while promoting updates to account for changes in future conditions.

Additionally, because of the long timeframes over which the LACPR measures will be implemented, it can be expected that goals and objectives may change over a period of years, resulting in the need to adopt measures that will match the changed conditions (Satterstrom et al., 2005). Dramatic changes to the economic base, population centers, and the physical shape of the coast within the life of the LACPR effort are possible due to rapidly changing conditions or from a single hurricane event; therefore, we should be prepared to institute significant changes in specific measures and in the overall plan during LACPR implementation. New information may also become available over time, e.g., improved estimates of sea level rise. For these reasons, a strategy founded on the principles of adaptive management will be essential to successful execution of the LACPR, both now and in the future.

Ensure Consistency between Programs

A need exists for assurance that USACE's civil works projects and regulatory decisions are integrated and consistent with coastal restoration efforts in Louisiana. In this context, "consistent" means that the wetland benefits from Federal and State coastal restoration activities would not be undercut or otherwise diminished by adverse wetland impacts associated with civil works projects (such as navigation and hurricane damage risk reduction projects) and development activities within the purview of the USACE's regulatory program.

The CWPPRA framers recognized the importance of such consistency and, therefore, included the following provision in the statute:

> *Consistency – (1) In implementing, maintaining, modifying, or rehabilitating navigation, flood control or irrigation projects, other than emergency actions, under other authorities, the Secretary [of the Army], in consultation with the Director [of the U.S. Fish and Wildlife Service] and the Administrator [of the Environmental Protection Agency], shall ensure that such actions are consistent with the purposes of the restoration plan submitted pursuant to this section [Section 3952(d)(1)].*

To promote such consistency, the USACE recommends a series of action items in the Louisiana Coastal Area (LCA) Ecosystem Restoration Study (USACE, 2004). The proposed action items cover navigation, regulated development, hurricane damage risk reduction projects, and other USACE projects. Additional background on consistency and descriptions of the proposed action items can be found in Chapter 6, Section 6.2 of the final Programmatic Environmental Impact Statement for the LCA Study.

The U.S. Congress is seeking to further address consistency by including provisions in the Water Resources Development Act of 2007 that would establish a team and integration procedure for the hurricane and flood damage reduction, navigation, and ecosystem restoration projects [Section 7004(2)].

The LACPR effort and Louisiana's Comprehensive Master Plan for a Sustainable Coast (Master Plan) represent significant progress towards consistency. For the first time, hurricane damage risk reduction measures are being planned in conjunction with coastal restoration measures. However, simply integrating the planning processes for hurricane damage risk reduction and coastal restoration does not guarantee that features such as levees will be consistent with coastal restoration. There are, for example, levee alignments in the Master Plan and under consideration within LACPR that potentially could cause large-scale hydrologic alterations, which could then undermine coastal restoration efforts. Moreover, neither plan fully addresses the range of other USACE projects and activities that could possibly conflict with coastal restoration, particularly with respect to regulatory matters and navigation. Thus, there remains significant interest and need to ensure consistency. Accordingly, the following actions are intended to further promote consistency efforts within the context of LACPR. Implementation of LACPR must:

- Form internal and external integration teams to ensure greater coordination and consistency among projects, studies, and other USACE activities;
- Review, update and incorporate the LCA consistency action items in the LACPR;
- Review the USACE's existing scientific capabilities relative to program integration and consistency (including the LCA Science and Technology program); and
- Identify additional measures needed to provide the science tools and processes necessary to further promote consistency among USACE programs.

Develop and Refine Models and Tools

As implementation of LACPR proceeds, additional models and tools, or refinements to existing models and tools will be needed both at the system-wide level, as well as at more localized, site-specific levels. More site-specific models with finer grids would be needed and the development of a system-wide hydrodynamic model will be necessary in order to maintain a comprehensive systems focus as restoration moves forward. Furthermore, additional data will need to be collected to further design the "next" tools needed to implement LACPR. The Science and Technology Program will work with managers and model leads to develop projects to resolve uncertainties associated with modeling and provide data for model refinement, calibration, and verification. These data will include items such as topographic and geologic data.

Conduct Peer Review

The National Research Council (NRC) LACPR Review Committee was established to provide external, independent review of the LACPR technical report. The purpose of this Committee is to ensure quality and credibility of the planning results, evaluation process and conclusions. Members of the committee include representatives from academia, private consultants, and the U.S. Geologic Survey. Each person was selected for his or her technical expertise in geography, geology, engineering, atmospheric, coastal or marine science, or planning.

As LACPR moves into subsequent phases, the LACPR team will continue to engage in independent technical review using and Planning Centers of Expertise to serve as technical peer reviewers.

Further, scientific investigations and project studies will be subject to a peer review by an independent panel of experts, the members of which shall represent a balance of areas of expertise suitable for the review conducted. The peer review could include detailed appraisals of the economic and environmental assumptions and projections, project evaluation data, economic analyses, environmental analyses, engineering analyses, formulation of alternative plans, methods for integrating risk and uncertainty, hydrologic and other models used in evaluation of economic or environmental impacts of proposed projects, and any other work products of the project study.

Program Management Structure

In order to execute LACPR, the team proposes a structure for plan management and implementation that will build upon the existing organization developed to manage the Hurricane Protection System program and incorporates a new project implementation approach centered on the RIDF process that will facilitate effective communication and decision making. A collaborative adaptive management approach supports this structure and is designed to be flexible to allow the new process to be managed adaptively and evolve over time to meet the needs of the Federal and State Governments. In addition, the proposed structure, detailed below, focuses on the need for a comprehensive systems approach to coastal protection and restoration, and incorporates the basic principles defined previously.

Decision Hierarchy

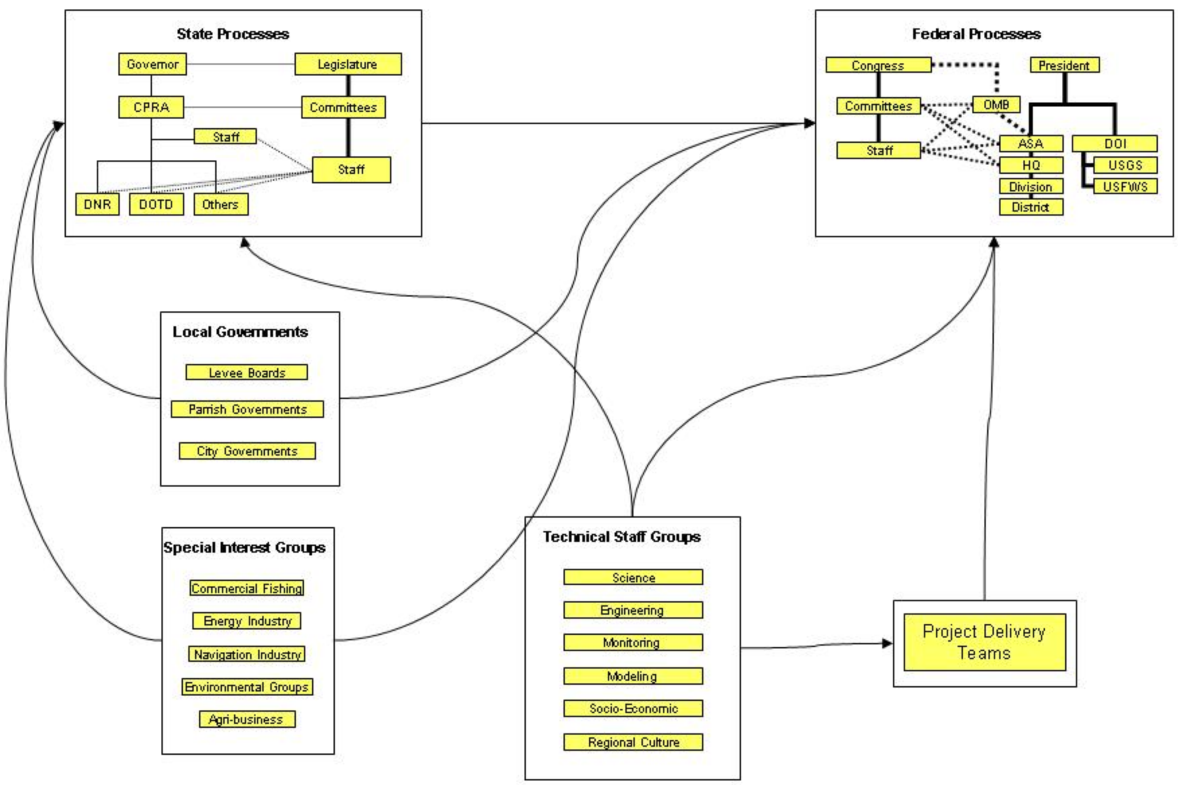
Traditionally, the Federal process for review and approval of civil works projects by the USACE has involved a number of Federal agencies, a chain of command, and a significant coordination between the Executive and Legislative Branches at a number of levels. Likewise, there are processes for review and approval of projects within Louisiana State Government (**Figure 8-2**). Additionally, local government entities and special interest groups have great stakes in coastal restoration and hurricane risk reduction and will argue to have their interests acknowledged and addressed.

Between these groups exists a number of communication channels (**Figure 8-2**). These traditional interactions, coupled with the complexity and expected duration of the LACPR, add to the challenge of successful communications and decision making. Considering the changing coast and other dynamic factors, a strong need to institute a new process has become evident.

A number of primary and secondary communication channels exist within the traditional project implementation process. Working within this framework will become increasingly challenging as the LACPR's multiple projects are implemented over multiple years.

Although not meant to replace any group's existing authorities or relieve any group's responsibilities, some of the traditional communication channels will phase out as this new program management structure becomes more effective in implementing LACPR projects. A memorandum of agreement between the State and Federal Governments is expected to mark the adoption of this new process, and it will be supported by appropriate legislation as necessary. This approach advantageously formalizes involvement from local governments, special interest groups, technical staff groups, and the project delivery teams.

Figure 8-2. Typical communication channels between groups.

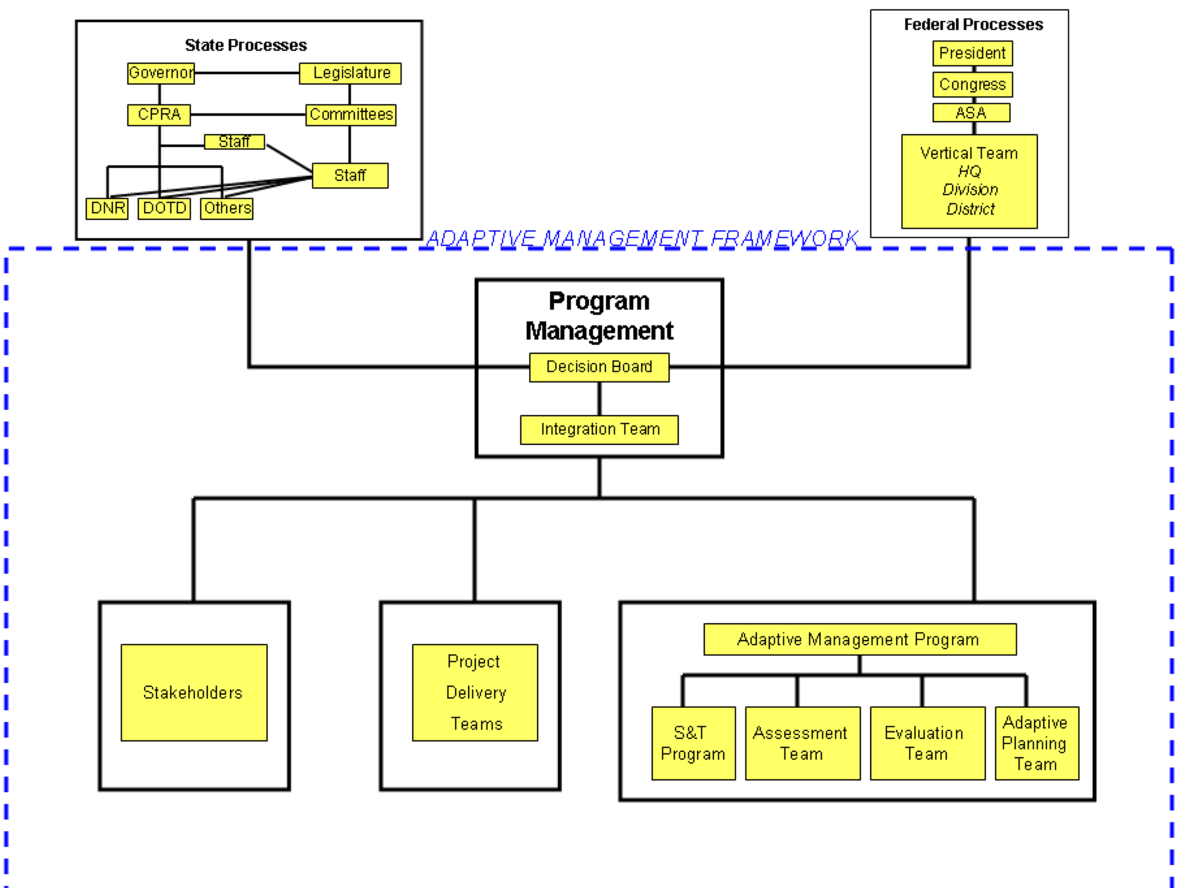


Decision Board and Integration Team

A key element of the suggested framework (**Figure 8-3**), which merges the Louisiana Coastal Areas (LCA) program management structure and the existing management organization of the USACE Hurricane Protection Systems program, is a Decision Board. The proposed Decision Board would be comprised of two representatives from the State and two from the USACE and would be responsible for the program's routine decision making and day-to-day management, through delegated authority at the programmatic level. Issues that fall outside of their authority would be vetted upward through State and Federal Governments to the appropriate decision making authorities. The two governments would define the Board's specific duties, which are expected to include prioritizing and scheduling work, planning and executing the budget, reviewing projects for consistency, directing and assigning resources, directing project reviews, and recommending projects for approval to higher authority.

In addition to regular program management, it is anticipated that the Decision Board would direct the application of the RIDF to ensure the inclusion of stakeholder, technical, and political views in the weighting of alternative plan evaluations and to direct the collaborative-adaptive management process that will address all aspects of long-term LACPR implementation. The Decision Board would coordinate all appropriate input to formulate and transmit formal recommendations for project implementations and other recommended actions to their respective governments in an effective and efficient manner that would improve the overall implementation process.

Figure 8-3. New framework for proposed management strategy for LACPR.



The Decision Board would be supported by the Integration Team, which would be staffed by senior agency personnel and supported by other staff and contract resources as necessary. In the proposed strategy, the Integration Team is the "working unit" of this new management structure, consolidating and funneling information from the Project Delivery Teams, Local Governments, Special Interest Groups, Technical Staff Groups and the Science and Technology

Program to the Decision Board. In addition, the Integration Team would use results of the MCDA to make recommendations to the Decision Board.

The Integration Team would act on and take direction from the Board. They would be the center coordination point for communication, issue management, technical staff interactions, program/project management, stakeholder interactions, and other critical implementation activities required by the Decision Board and the program management process. The Integration Team would identify, organize, and process all issues and other aspects of day to day LACPR implementation. They would manage the Decision Board's routine agenda and prepare "decision packets" for the Board that includes alternative and recommended courses of action.

By applying adaptive management, the Decision Board would aggressively resolve engineering, scientific, policy, and other issues (reduce uncertainties/answer unanswered questions) that prevent progress toward implementation, then direct the Integration Team to identify, collect, and manage the flow of issues and their resolution. Additionally, the Integration Team would identify issues and pertinent information collected from the stakeholders, agency staff, and academia and would maintain an inventory of issues and their status of resolution.

The Decision Board would be expected to meet on a regular basis to process issues, take actions, give direction to the Integration Team, and prepare recommendations for consideration and approval by the two government entities. For many issues, a management or "executive" decision by the Decision Board would bring resolution without further action. When the Board requires more information for decision-making, or to send an issue or recommendation upward in the Board's State and Federal authority chains, the Decision Board, through the Integration Team, would direct the appropriate team to investigate the issue further and return it to the Decision Board later for final resolution. This further investigation would often involve scientific, engineering, monitoring and assessment, research, or other investigations. The Decision Board would direct resources to execute these directives. As the Integration Team resolves issues, they would be responsible for posting the resolutions in an issue-inventory database to ensure that all concerned parties know which issues are resolved and thereby eliminate the recycling of previously resolved issues.

The Integration Team would work very closely with technical staff, the Project Delivery Teams, and other groups, using RIDF and other adaptive management tools to continuously integrate the best new information into processing action items for the Decision Board. This includes issues for resolution as discussed above as well as the review of and recommendations for approval of projects. The Integration Team may include members from groups (including the Project Delivery Teams, Science and Technology Team, Adaptive Management Team, and the MCDA/RIDF team) as the Decision Board deems necessary.

This improved program management process would increase the overall success of LACPR. Successful implementation requires the right resources coupled with the right timing to support its various components. In order to fully support this new process, certain existing limitations on adaptive management would have to be changed. Current policy guidance and budgeting procedures found in USACE planning guidance ER 1105-2-1100 (Apr 2000) limit adaptive management costs to no more than three percent of the overall project cost and monitoring to one percent, both with limited durations. Staying within the confines of current policy would be difficult within the LACPR because of the large number of individual projects and how beneficial knowledge gained passes to subsequent projects. Additionally, complex, large-scale projects, such as LACPR, implemented over long time periods exhibit inherently high-risk levels and uncertainty that must be reduced to achieve successful implementation. Adaptive management's structured process offers the best strategy for reducing uncertainties methodically to acceptable levels, which can allow implementation to proceed, providing feedback through monitoring. In addition, the process facilitates continuous improvement to current operations, subsequent planning, design, construction, and operations and maintenance.

The current USACE planning guidance may be appropriate in some LACPR applications, however, for many, it appears to be too limiting and would not afford LACPR the flexibility necessary to be implemented according to this strategy. In such cases, specific planning guidance memorandums would be composed to improve effectiveness and efficiency of LACPR implementation. When needed, the Decision Board would task the Integration Team to compose the memorandum. The Decision Board would approve what falls within their authority and direct what requires approval from higher authorities upward through the Vertical Team. Along with the consideration for adoption of this program management process, it is recommended that the current limitations of time and money on adaptive management be relieved for LACPR. If allowed, the Decision Board and their upward decision chains in State and Federal Government would regulate this relief, allowing adaptive management to increase implementation effectiveness and reduce overall project costs. Permitting LACPR's use of adaptive management to its fullest potential coupled with the availability of necessary resources would assure effective hurricane damage risk reduction and ecosystem restoration.

Stakeholders

Stakeholder engagement and the use of a collaborative approach to problem solving are critical components to ensure the success of LACPR. Because of the size and complexity of LACPR, it is important that stakeholders are not just involved, but actively engaged in decision making and problem-solving at the program and project levels. Engaging stakeholders in project planning, design, implementation, and evaluation has many benefits including: (1) building better understanding among stakeholders; (2) promoting relationships and trust as well as establishing lines of communication; (3) providing an opportunity for cooperative learning (i.e., issues that may be confusing, unclear, or unknown at the initiation of the project); (4) providing a mechanism to identify and address key issues and concerns; (5) creating networks for "honest dissemination of new understanding as the project/program unfolds; (6) enabling development of creative solutions that address the unique mix of stakeholder interests; and (7) increasing the likelihood of program/project success (USACE, 2007). The LACPR team recognizes that all organizations, entities, and individuals have interests and is committed to addressing these interests proactively within the context of the project/program in order to reduce the likelihood of delay and help remove any obstacles.

Project Delivery Teams

To plan and implement its large number of individual projects, the USACE utilizes multiple Project Delivery Teams, which are interdisciplinary teams of staff professionals from the USACE and sponsoring and cooperating agencies, each led by a USACE Project Manager.

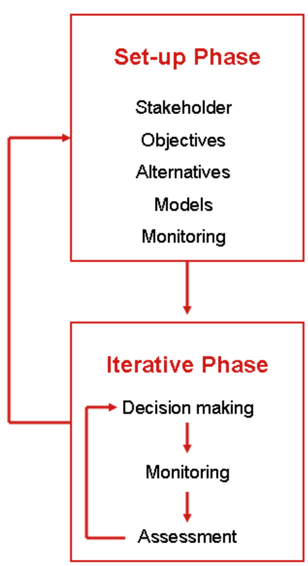
Under LACPR, each individual project would have a Project Delivery Team that includes the disciplines and represents the functions of planning, engineering, construction, operations, and real estate that will provide the needed expertise for that specific project. The team would conduct planning studies, perform project designs, and oversee the building of projects by construction contractors. Numerous technical groups are available for support on program and project planning, and for engineering design.

Adaptive Management

A comprehensive strategy for the adaptive management of LACPR would be developed in consultation with stakeholders and participating state, federal, local, and tribal governments. The discussion below makes recommendations for an Adaptive Management Program structure and includes essential components of a successful strategy.

Adaptive management principles should be applied during LACPR planning activities at both the system-wide and project-levels. The system-level approach addresses adaptive management on a regional and ecosystem-scale and the project-level approach focuses more on localized impacts and responses. Applications of adaptive management should occur in two phases as suggested by the *Adaptive Management: U.S. Department of the Interior Technical Guide (2007)* (**Figure 8-4**). A set-up phase would involve the development of key components and an iterative phase would link these components in a sequential decision process. Elements of the set-up phase include: stakeholder involvement, defining management objectives, identifying potential management actions, identifying or building predictive modeling tools, and creating monitoring plans. The iterative phase uses these elements in an ongoing cycle of learning about system structure and function, and managing based on what is learned. The elements of the iterative phase include decision making, follow-up monitoring, and assessment.

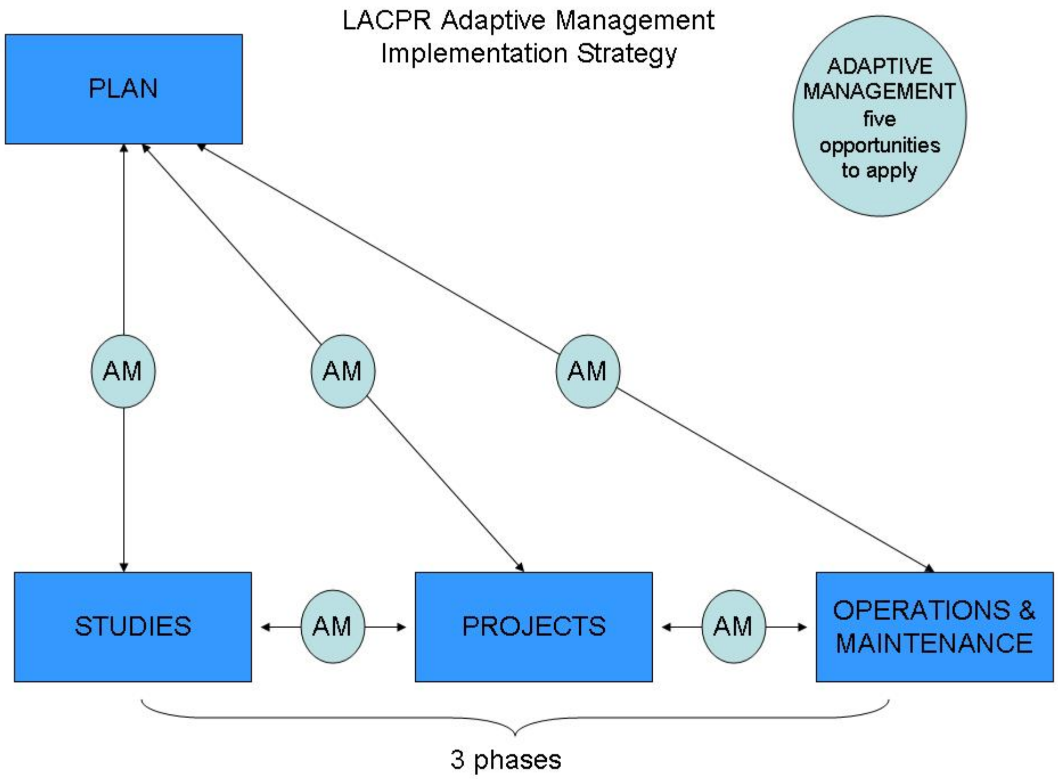
Figure 8-4. Two-phase learning in adaptive management.



Source: Williams, B.K., R.C. Szaro, and C.D. Shapiro. 2007.

There are many advantageous opportunities for adaptive management to be applied in LACPR (**Figure 8-5**). Prospects not only include the traditional areas of ecosystem issues, but also include engineering, construction, and socio-political issues. The LACPR adaptive management strategies should start by identifying what is "known" and "unknown" about each system and its response to hurricane risk reduction and restoration activities. This will promote focusing on important uncertainties that must be addressed so that adaptive management processes can resolve them.

Figure 8-5. Five key adaptive management utilization opportunities within planning and project implementation.



Adaptive Management Program

As decisions are implemented based upon best available science, technology, and socio-economic data, a structure and process must be in place to acquire better information and adjust the implemented actions accordingly to improve the probability of achieving the goals and objectives for implementation of the LACPR plan. Such a process requires the development of key tools, such as sound baseline data and monitoring over time and space, models, data management, and continued research – to provide program/project manager with updated information for planning restoration and hurricane protection projects, and on the effects of management actions designed to achieve these same tasks. As new information for restoration and hurricane protection efforts become available, the progress of LACPR toward meeting the restoration and protection goals and objectives can be defined and measured.

The Adaptive Management Program would provide essential support to LACPR in meeting its goals and objectives through the application of a system-wide perspective to the planning and implementation of LACPR. Under this Program there are four teams: Science and Technology, Adaptive Assessment, Adaptive Evaluation, and Adaptive Planning. Each team would consist of a multiagency staff from the appropriate disciplines, including engineering, planning, science, economics, sociology, modeling, and resource management. Each team would have their own responsibilities within the adaptive management framework but would work closely with the other teams in order to fully implement the proposed strategy.

An Adaptive Management Office would be the focal point for activities of Adaptive Management Program and would provide a physical location and primary point of contact for all Project Delivery Teams, agencies, and individual stakeholders with interests in science, technology, and adaptive planning, assessment, and evaluation. It would communicate regularly and efficiently with the LACPR Integration Team. The Adaptive Management Office would consist of a Director and appropriate staffing to meet required mission tasks and goals. Funds would be allocated to the Adaptive Management Program by the Decision Board to address programmatic adaptive management needs.

Science and Technology Program

The Science and Technology Team would be responsible for providing the necessary science, including social and economic analyses, and technology, to effectively address coastal restoration and hurricane protection needs. They would provide analytical tools and recommend to the Assessment Team the appropriate modeling, monitoring, research, and/or experimentation to ensure that current issues of uncertainty can be addressed. In addition, they would be responsible for implementation of the monitoring and assessment plan, including the collection of baseline and project performance data. The Science and Technology Team would conduct data mining, identifying data gaps, and collect new date where needed as directed by the Assessment Team. They would also be responsible for setting up a system –wide database to house and manage all scientific data for coastal Louisiana.

A Science and Technology Program was established under LCA by the USACE and the non-Federal sponsor to effectively address coastal ecosystem restoration needs, and to provide a strategy, organizational structure, and process to facilitate integration of science and technology into the decision making process (USACE, 2004b). The LACPR program proposes to utilize the LCA Science and Technology program in order to ensure that the best available science and technology are integrated into planning, design, construction, and operation of LACPR projects.

Assessment Team

An Adaptive Assessment Team would be responsible for interpreting project performance based on the analysis of information obtained from the Science and Technology program, including research, monitoring, and modeling. They would create, refine, and provide documentation for a set of conceptual models for the planning area and create and refine a set of attribute-based performance measures for LACPR. In addition, they would work closely with the Science and

Technology Team to design and review the system-wide monitoring and data management program.

Evaluation Team

The Evaluation Team would be primarily responsible for the management of the tools used to forecast the performance of the plans and the designs relative to desired objectives. They would support the Science and Technology Team in the development and refinement of these tools which include predictive models and the MCDA. The Evaluation Team would evaluate system-wide planning activities and provide guidance to the Project Delivery Teams regarding alternative evaluation for project level adaptive planning. In addition, this team would develop and refine regional evaluation performance measures, review project-level goals, objectives, and performance measures from a system wide perspective.

Adaptive Planning Team

The LACPR Adaptive Planning Team would be primarily responsible for developing recommendations refinements and improvements to LACPR throughout the implementation period. This team would make sure the right questions are being addressed in a structured format and that the process for answering them and disseminating the information is collaborative and transparent. Additionally, this team would work to ensure the implementation of the most important projects first, the optimum order of projects, and that only implementable projects broadly supported by the two governments and stakeholders are authorized and funded.

They would provide guidance and support for project level adaptive management and would verify integration of the Adaptive Management Program with appropriate planning and operations planning activities at the USACE and with the State of Louisiana.

Stakeholder Involvement

To initiate this adaptive management strategy, the LACPR stakeholders, having been consulted through public meetings and workshops, defined the goals and objectives of LACPR, and described the problems and opportunities associated with these goals and objectives. The USACE, in conjunction with its State of Louisiana partners, held scoping meetings across the State to provide information to the public and stakeholders, and to solicit feedback. The USACE developed its list of stakeholders based on its past relationships with the stakeholder community, input from its state partner, as well as cooperative efforts with State, community and civic leaders.

As the process has moved forward, the LACPR team has also held stakeholder sessions to elicit metric weights. This data is vital to the Multi-Criteria Decision Analysis (MCDA) and being incorporated into this evaluation tool. As of January 2008, the USACE has engaged the NGO/Science community in three workshops, while two rounds consisting of four meetings each across the state have been held to engage local elected officials, parish governments, various civic organizations, business interests and others. The team also plans to hold two additional rounds of meetings in 2008.

In addition, the team will continually engage and consult stakeholders as project planning and implementation progresses, and conduct similar efforts at the appropriate scale to constantly improve the planning process.

Goals and Objectives

LACPR goals and objectives were identified at the beginning of the planning process. These goals and objectives are important elements of the LACPR adaptive management process. They address stakeholder interests, where possible, in order to ensure stakeholder involvement and clearly link the problems to opportunities and solutions. This linkage will be used to guide the development of conceptual models (see below) to identify stressors, working hypotheses, and key uncertainties which will be used to guide the process of selecting assessment performance measures and indicators, and evaluation performance measures (MCDA performance metrics).

Performance Measures/Metrics

Performance measures would be used during two adaptive management processes: plan evaluation (evaluation performance measures/MCDA performance metrics as previously discussed) and assessment of actual plan performance (assessment performance measures). In many cases, these would be the same, allowing predictions to be compared to actual responses. In other cases, tools may not be available for project evaluation. However, the measure is important enough, or shows a strong enough linkage, to proposed hurricane damage risk reduction or restoration activities that it should be monitored (assessed) to track project effects. Additionally, for each assessment performance measure (to be identified in the conceptual model process), interim goals, hurricane risk reduction, and restoration targets would be established. The progress towards risk reduction and restoration would be assessed at regular intervals as LACPR is implemented.

Monitoring Plans (Assessment)

Monitoring programs are a key component of adaptive management. Monitoring provides feedback between decision making and system response relative to management goals and objectives. An essential element of adaptive management is the development and execution of a scientifically rigorous monitoring and assessment program to analyze and understand responses of the system to implementation of plans.

The Assessment Team, under the Adaptive Management Program, would provide leadership and guidance for all monitoring and assessment efforts for LACPR. This team would design monitoring programs to collect data essential for the development of decision-support tools (i.e., models, MCDA, etc) and to assess the overall goals and objectives of LACPR. Working closely with the other teams in the Adaptive Management Program, including the Science and Technology Program, the Evaluation Team, and the Adaptive Planning Team, data standards, monitoring guidelines, and assessment criteria will be clearly set so as to better track hurricane risk reduction and coastal restoration efforts. The Assessment Team would also ensure that project-specific monitoring plans and system-level monitoring strategies clearly describe desired ecological conditions such that management actions throughout the life of LACPR could be optimized.

Working closely with the Science and Technology Program, the Assessment Team would design and use conceptual models that would help drive monitoring efforts. Inherent in this effort is the use of conceptual models of ecosystem function that provide hypotheses of system response to management actions over various spatial and temporal scales. The conceptual models guide the identification of performance measures and ultimately, provide a framework for targeting variables and tracking the status of ecosystem responses. More specifically, the variables that get targeted would be those that can be incorporated back into the MCDA and other decision-support tools to test the working hypotheses that drive management actions. Initial conceptual models would need to include such variables as anthropogenic sources for changes in the ecosystem, potential ecological stressors, and desired responses to the ecosystem. In addition, they would encompass links between disturbances, effects, and responses within the system which require a project-level understanding of the desired ecological endpoints. Furthermore, as conceptual models are developed and enhanced throughout the life of the program, the monitoring strategies would subsequently be improved, data gaps identified, and critical uncertainties addressed, enhancing the ability of the MCDA and other decision-support tools to produce successful restoration and protection alternatives.

The monitoring and assessment effort will only be successful if the data collected meet the needs of all the teams under the Adaptive Management Program. Communication among the teams would be essential, requiring well defined data delivery and feedback mechanisms to support program management decisions. The Science and Technology Program would ensure that the monitoring plans are implemented and that the monitoring data are utilized to assess project and program progress, evaluate and improve models, and to evaluate potential changes to management actions under the Adaptive Management Program. Once the feedback mechanisms are defined, understood and reiterated throughout the life of the program, uncertainties would be reduced and better management decisions could be made.

The monitoring and assessment approach would utilize and build upon data availability through existing monitoring systems such as CWPPRA's Coastwide Reference Monitoring System. An assessment would be initiated of all available data collection conducted by existing monitoring and modeling programs. This assessment could then be compared with the project and program needs of the LACPR to support optimized monitoring and assessment planning. As the MCDA would be a primary tool used for management actions, it would be critical that monitoring results tie directly into assessing the MCDA so that individual project and program results can be improved.

Risk Informed Decision Framework

During the planning process, performance evaluation metrics (refer back to **Table 6-1 or 7-2**) establish the degree to which the plans satisfy the planning objectives and stakeholder values. These involve quantification of a complex array of human and natural system drivers. These metrics can be derived from mathematical models, empirical data, or expert opinion. Once calculated, the metric values are input into the MCDA which is the primary tool of the Risk-Informed Decision Framework (RIDF). The MCDA provides the basis for the ranking of the performance of alternative plan formulations based on the performance measures. In addition, the RIDF would identify risk, account for planning uncertainties, identify data gaps, and establish confidence levels for planning decisions.

The RIDF process (see the *Risk-Informed Decision Framework Appendix*) forms the quantitative basis of LACPR decision making and the adaptive management processes. Following the six-step USACE planning process, the RIDF supports decision making by concentrating the problem into a transparent, understandable, and tractable format. Using this process enables planners and managers to address multiple objectives, such as conflicting stakeholder values, qualitative and quantitative performance assessments, and uncertainty in the natural, social, and economic environment in which implementation decisions must be made. The RIDF, through use of the MCDA tool, uses input values for selected metrics, combined with information about stakeholder and decision maker values and weighting functions, to generate an overall score for each plan being evaluated. As part of the adaptive management process, the MCDA would reevaluate plans as new information becomes available or unexpected changes occur.

The RIDF would also be a focal point for the adaptive management strategy during plan implementation. Existing program level performance measures would be maintained where appropriate and new measures may be recommended as deemed necessary for adaptive management. The RIDF would also be used to guide project level planning and adaptive management although a new set of performance measures may be used depending on project specific goals and objectives.

Required Decision Documents

Any projects identified as part of the LACPR comprehensive plans would require planning reports, engineering design documents, and NEPA compliance as follows.

National Environmental Policy Act (NEPA)

Depending on the level of anticipated beneficial or adverse impacts for projects as they are authorized for further detailed analysis and design, a decision will be made to prepare a standard Environmental Impact Statement or Environmental Assessment. All policy, statutory, and regulatory mandated environmental documentation and compliance procedures will be adhered to in each case

Planning Reports

Recent LCA authorizing legislation calls for the development of a Comprehensive Restoration Plan that will be integrated with the LACPR plan and consistent with the State Master Plan. The legislation further directs that the restoration measures contained in the comprehensive plan be prioritized based on their ability to create coastal wetlands and provide flood protection to communities in order of population density and designated level of protection. This comprehensive restoration plan will integrate both the findings of LACPR and LCA efforts as well as those of the State’s Coastal Protection and Restoration Authority (CPRA). The comprehensive plan is require to be submitted one year from the date of enactment of the WRDA 2007 legislation. Additional planning reports will follow Federal planning requirements initially issued by the U.S. Water Resources Council in 1983 unless modified by higher authorities.

Engineering Design

Contents of reports must be in accordance with ER 1110-2-1150, Engineering and Design for

Civil Works Projects. A documented feasibility level design and cost estimate is required to request authorization for project construction unless modified by higher authorities. Design Documentation Reports are a record of the final design after the feasibility phase. A Design Documentation Report is required for all engineering design products and serves as the technical basis for the plans and specifications and a summary of the final design. A series of Design Documentation Reports would be produced for individual project features.

Implementation Strategy

Implementation of the LACPR plan will require a long-term commitment, which will take place over the next several decades, requiring resources from the Federal, State, and local governments in the region. The implementation process will be developed based on an analysis of the plan features and ongoing Federal and State programs and projects. This implementation process will require use of existing authorities and creation of new authorities as the implementation progresses over time.

Section 9. LACPR Path Ahead

Beyond the technical and planning work previously described in this report, the LACPR team will complete additional tasks which are described in the following sections:

- Complete independent technical review, including model certification;
- Initiate and complete external peer review;
- Reevaluate metric data;
- Complete evaluation and comparison of alternative plans using MCDA and stakeholder input;
- Perform a systems analysis of the Gulf coast in coordination with Mississippi;
- Assemble a coastwide comprehensive plan based on stakeholder input;
- Integrate the MRGO components into the comprehensive coastwide LACPR plan; and
- Evaluate recommendations made by the Dutch and others.

The team has outlined a full-scale public involvement plan to include continued interactive public meetings and events. Work will continue to fully coordinate this effort with other ongoing recovery planning efforts being conducted in Louisiana. Most importantly, the LACPR team will continue to work closely with the State of Louisiana in the utilization of its Master Plan for hurricane risk reduction and coastal ecosystem restoration.

Independent Technical Review

An initial independent technical review of the LACPR effort has been conducted; however, independent technical review is an ongoing process. Following the initial independent technical review, the LACPR team will complete additional independent technical review coordination for model and spreadsheet applications that will require certification. The majority of the data processing tools being applied in the LACPR effort are spreadsheet and GIS-based applications. As such they will be certified through the independent technical review process.

External Peer Review

Following completion of an initial independent technical review of the Draft Technical Report an initial external peer review will be undertaken. The National Academy of Sciences will provide an expedited six week review culminating in a letter report. The external peer review comments will be integrated prior to application of the MCDA tools to the LACPR planning process. The National Academies will also provide an extended review of the Final Technical Report.

Reevaluation of Metric Data

The initial detailed evaluation of the economic metrics for the array of alternatives remaining after completion of the final (Tier 3) screening resulted in some very large residual damages being identified under with-project conditions for structural and comprehensive (combined) alternatives. These high residual flood damages, particularly those associated with the 10-year frequency rainfall/storm event, did not appear to be reasonable in many areas when compared to results of previous studies, e.g., the South East Louisiana (SELA) interior drainage study conducted in 1995 and to documented historical events of similar magnitude.

In addition, the independent technical review of the Draft Technical Report also expressed numerous concerns regarding these high residual damages. The focus of independent technical review comments was that the source of damages was not clear and needed further explanation; structural plans were not formulated to consider the runoff and interior drainage component and as such were not considered complete; and comparison of nonstructural and structural alternatives was biased to the nonstructural plans.

In response to the independent technical review comments, it was noted that the evaluation of structural alternatives may be unfairly scored in rankings; that the high residual damages were primarily associated with interior drainage and assumed 10-year rainfall amounts; nonstructural plans can significantly reduce the 10-year damages while structure plans do not; and the 10-year damages may have been overstated because of several cumulative effects resulting from the simplified assumptions used in the original evaluation of damages. As such, the LACPR team agreed to conduct some sensitivity analyses for a couple of the planning subunits in Planning Unit 1 to test assumptions used and to determine whether a full scale reevaluation of economic damages was needed. Areas selected for further analysis were the East Jefferson planning subunit and the Slidell area.

Potential problem areas identified that could be impacting the calculation of residual damages, with focus on the 10-year event damages, included: water surface elevations (stage-storage relationships, pumping capacities, impact of locally constructed levees, 10-year rainfall estimates, and impact area of 10-year storm surge); assumed mean ground elevations and first floor adjustments; emergency cost calculations; placement of new development in the 2010 base condition; and accounting for vehicle damages.

Based on a detailed critique of the potential problem areas identified above and assuring there was a solid technical basis for any proposed revisions/refinements to damage assessments, it was concluded that:

- Assumed 10-year water surface elevations were too high in some areas based on historical data and previous studies.
- Assumed pumping capacities in some areas (e.g., Metro New Orleans) did not accurately reflect authorized pumping capacities and performance.
- Delineation of some planning subunits needs to be modified and new water surface elevations developed for such.
- Areas showing increased water surface elevations between without and with project conditions need to be reexamined to confirm whether potential inducements are realistic.
- Calculation of mean ground elevations are being impacted by the elevations of streets, canals, other water areas, and levees, thereby misrepresenting actual elevations of structures when first floor adjustments are made.
- Emergency costs need to be aligned with start of damages for structures.
- New development (structures) increment in the 2010 Base Condition should be placed at the 100-year elevation instead of at elevations for existing structures.
- Vehicle damages need to be separated from structure damages for nonstructural plans.

Applying the above adjustments to damage calculations for 2025 (at 90% confidence level, no sea level rise, dispersed land use, and high growth condition) for the East Jefferson area, the 10-year event damages were reduced from $718 million to approximately $31 million and the Equivalent Annual Damages (EAD) were reduced from $174 million to $98 million (a 44 % reduction from original estimated values).

Applying the above adjustments to damage calculations for 2025 (also at the 90% confidence level, no sea level rise, dispersed land use, and high growth condition) for the Slidell area, the 10-year event damages were reduced from $691 million to approximately $49 million and the Equivalent Annual Damages were reduced from $135 million to $64 million (a 53 % reduction from original estimated values).

Based on this sensitivity analysis it has been concluded that the original estimated residual damages have been greatly overestimated, particularly for the 10-year and 100-year frequency events. This evaluation impacts plan formulation, final ranking of alternatives and the ultimate report recommendations.

Based on this finding, the team has initiated a full scale reevaluation of all economic damages, including the reformulation of nonstructural alternatives, for all alternatives in each of the five planning units. This reevaluation effort will be conducted currently with the regional system analysis, discussed later in this section.

As part of this reevaluation effort, the district team has also reformulated structural alternatives for the Lake Pontchartrain North Shore (which is addressed in the Structural Plan Component Appendix); will incorporate new 10-year water surface elevations for 10-year storm events for areas exterior to existing and/or proposed levees; and will update damage estimates to 2007 price levels to be comparable with cost data.

Evaluation and Comparison of Alternatives using MCDA and Stakeholder Input

Additional evaluation must be completed in order to rank and compare alternative plans. Metric results must be compiled and verified. Once metric outputs have been verified, this data will be submitted for stakeholder consideration through the MCDA process. At stakeholder workshops, the LACPR team will use expert and stakeholder groups to elicit weights for the metrics. The purpose of these meetings is to refine the decision model for ranking plans, gather meaningful input from stakeholders which will guide the ranking of alternative plans, and give participants the opportunity to explore rankings by offering sample demonstrations regarding how plan rankings change based on the weight metrics are given. Ultimately, preferred plan selection is based on a group decision process from which no single best solution is likely to emerge, but through which multiple criteria and perspectives can be dealt with in a transparent fashion. Consequently, stakeholders are encouraged to resolve differences and move toward consensus.

Stakeholders will provide weights for metrics and those weights will influence plan rankings. Following the stakeholder workshops, metric data will be combined with information about values and weighting functions for the various metrics to generate an overall score for each plan being considered. These scores will allow direct comparisons across all plans and ranking plans in relation to each other. Such scores can be used to evaluate plans against the without project condition, as well as to compare the performance of individual plans.

Sensitivity analysis will be performed to offer decision-makers and stakeholders a tangible understanding of the relative importance of the metrics and the robustness of the plan rankings. When used to answer questions of particular interest to decision-makers and stakeholders, sensitivity analysis can be an effective tool for establishing confidence in rankings and ultimately, the decisions made and the planning process.

Systematic and Regional Integration of LACPR with Mississippi Coastal Improvements Program

The hurricanes of 2005 affected the entire region of the northern Gulf of Mexico from the panhandle of Florida to the Texas coast causing direct destruction to the immediate coast and its population centers. It also had unprecedented impacts to the much broader region from the subsequent migration of the affected population, wholesale disruption of the region’s economy, disruption of the region’s educational infrastructure, and untold impacts on the human resources of the region. Although Congress authorized two separate studies with slightly different objectives to address the Louisiana and Mississippi coasts, the USACE has taken a systematic and regional approach in formulating solutions and in evaluating the impacts and benefits of those solutions. In addition to the regional impacts of the hurricanes of 2005, the two states share key resource issues including shoreline erosion and barrier island loss, wetland loss, salinity intrusion, and storm surge and wave run-up. The barrier islands reduce wave energy and help significantly in reducing erosion to the mainland. Wetlands, including marshes and near shore marine and estuarine habitat, are the nursery grounds for the entire marine food chain in the Gulf of Mexico. Like the barrier islands, wetlands also help to reduce wave energy. Linked to the degradation and loss of the wetlands and barrier islands is the increase in salinity in the estuarine areas of the Mississippi, Breton, and Chandeleur Sounds. The increasingly scarce sound areas of the United States require a delicate mix of fresh and salt water to provide habitat for oysters, shrimp, sturgeon, and other fisheries, which provide an important economic resource for both states.

The LACPR and Mississippi Coastal Improvements Program (MsCIP) teams are working together to solve issues at the local, regional, and national levels. Multiple focus groups, public meetings, and regional workshops have been held to make sure that the solutions presented in this report are comprehensive in nature, and to maintain the delicate balance between human and natural resources. Both efforts used the same plan formulation strategy and shared the use of many technical tools required to perform evaluations. To this end, both teams are considering structural, nonstructural, and coastal restoration measures resulting from the plan formulation process. To ensure consistent communication and coordination, both teams have attended critical meetings regarding goals and objectives, plan formulation, and independent technical review and external peer review efforts. All modeling efforts have been well coordinated, and both teams made use of, and jointly coordinated, the efforts of USACE laboratories, Centers of Expertise, and independent technical review and external peer review teams involved in the studies. In addition, the development of the Risk Informed Decision Framework has been a joint effort of the two studies.

The team is considering all potential impacts, both adverse and beneficial, without regard to geographic boundaries. Measures that induce adverse impacts either must be eliminated from further consideration or their impacts must be satisfactorily mitigated on a regional basis. Several measures may have beneficial impacts beyond specific planning boundaries. For example, the diversion of freshwater from the Mississippi River to Lake Borgne via the Violet Canal could reduce saltwater intrusion in the Mississippi Sound south of Hancock County, Mississippi and provide much needed sediments to the Biloxi Marshes of Louisiana. Also, the systematic restoration of the coastal sediment budget and sand transport system along the Mississippi barrier islands could provide benefits to eastern Louisiana.

In both the MsCIP and LACPR studies, the regional influences of several alternative plans on storm surge levels were examined with regional storm surge and wave modeling efforts. The regional surge/wave model was designed specifically with this requirement in mind by having model domains and grid meshes that encompassed both Louisiana and Mississippi, and by developing the models consistently (for example, similar grid resolutions for both models).

A regionally consistent definition of the hurricane hazard was also developed. A multi-disciplinary team was assembled to characterize the probabilities of different hurricanes that could impact the northern Gulf of Mexico region. The team’s work fully utilized cutting edge modeling to develop a unified coastal flooding methodology that is being applied across agencies for use in multiple states. The unified approach involves coupled regional storm surge and nearshore wave models (the same approach originally taken by the IPET). The team developed a number of new insights into the behavior of hurricanes. One notable and extremely important finding was the tendency for all major intense hurricanes to decrease in intensity prior to landfall. The team developed a regionally-consistent approach for defining hurricane probabilities and for calculating probabilities associated with hurricanes having certain characteristics (track, intensity, size, forward speed).

Both the MsCIP and LACPR studies are presently considering several alternatives to divert freshwater from the Mississippi River or other sources as a mechanism for promoting a reversal of the historic increase in salinity in the Mississippi Sound/Biloxi Marsh area. The intent of such a diversion is to build wetlands, support fresher marshes and improve oyster reef health and productivity, thus enhancing economic and ecological value. However, diverted freshwater usually carries more sediment and nutrients than marine water that may result in areas of excess nutrients, and thus cause algal blooms and eutrophication, greater light attenuation, and changed substrate characteristics. Therefore, the team must evaluate the system-wide impacts of freshwater diversions carefully. Spatially explicit evaluations of habitat change over large areas are required for such system-wide impacts evaluation. The positive and negative aspects of various diversion scenarios are being evaluated to assess their ability to meet the goals of both MsCIP and LACPR.

During the next steps of LACPR and MsCIP, the joint teams will collaborate at a Northern Gulf of Mexico integrated systems scale. To ensure a fully coordinated approach, a “systems analysis” will be completed to support the development of a comprehensive coastwide plan, consistent with all planning objectives and metrics and commensurate with the potential recommendations and the level of detail in the reports. This systems analysis will be initiated with the current LACPR and MsCIP efforts and continuously updated and refined based on evolving recommendations and direction in the ensuing phases. This systems analysis will include modeling of the storm suite used to determine surge and wave heights used in the development of measures and alternatives in the MsCIP and LACPR reports.

The purpose of this effort will be to identify common stakeholder agreement on the configuration, performance, and cost of alternatives with a goal of achieving no adverse impacts, levels of risk reduction, and coastal restoration features. The LACPR and MsCIP teams will hold joint meetings with stakeholders of the coastal areas in Louisiana and Mississippi during the winter and spring 2008 to accomplish the following:

- Explain the plan formulation process for both studies relative to coastal restoration and risk reduction.
- Present the measures and alternative plans evaluated by both studies.
- Describe the performance, costs, and potential adverse consequences for each alternative plan.
- Solicit stakeholder input for both studies in joint meeting sessions to identify points of agreement and disagreement regarding the makeup, performance, and costs of alternative plans.
- Interact with the stakeholders of both studies for screening, refinement, and/or reformulation of alternative plans from an integrated systems perspective.
- Screen, refine, and/or reformulate alternative plans as necessary to reflect common agreement on configuration, performance, and cost to achieve no adverse impacts, risk reduction, and coastal restoration.
- Describe requirements for further alternative plan development and analysis.

Coastwide Comprehensive Plan

In the case of LACPR, a preferred plan will not be selected until technical results have been shared with stakeholders and the public and stakeholder values have been solicited. The preferred plan will be based on all the information collected in the planning process, including all the values, weights, and metrics used to score and rank the measures including input from the MCDA analysis.

The basic geographic scale of plan development in the LACPR effort has been the planning unit. As the MCDA analysis and stakeholder engagement narrows the range of effective, efficient, and acceptable plans the final step will include assembling the possible combinations into a comprehensive coastwide system. Plan compatibility across the coast will influence the final identification of plans in each of the planning units in addition to their performance across the range of metrics and the MCDA analysis.

Following the ranking of protection and restoration plans by planning unit using the MCDA tool, the team will perform a multi-objective optimization to identify and order comprehensive system alternatives. Applying the MCDA output will provide a normalized score between zero and one for each alternative plan. These MCDA score values are readily additive, as are life cycle costs, and allow an aggregation of plans across planning units. Use of the MCDA in each planning unit to create rankings prior to assembling coast wide system alternatives also ensures that significant variations in metric weight values across planning units are preserved in the coast wide system alternatives. This approach will also allow the planning team to identify break points in the rank scoring in each planning unit and focus the assembly of coast wide system alternatives on the most efficient planning unit based combinations.

The multi-objective optimization will assemble potential combinations of plans from across the five planning units. The planning team will designate those plans dependent upon one another from planning unit to planning unit as well as those plans that are exclusive of one another and cannot be combined. This will ensure that all necessary combinations are included and all inappropriate combinations are excluded from the analysis. Once the team develops all combinations, those combinations that produce identical aggregate performance scores at a higher cost can be screened away leaving an ordered set of the most efficient plan combinations.

While the comprehensive coast wide system alternatives are those that incorporate plans in all of the five planning units, an incremental ordering of individual planning unit plans ascending through the coast wide combinations for all five planning units could provide insight to the potential priority of plan implementation. Once decision-makers select a plan, the team will conduct a qualitative or quantitative assessment of any risks created by the plan. A created risk would include increases in lives and property at risk attributable by constructing a levee for example. Congress and the Administration will make the ultimate decision to authorize projects and appropriate funds to implement projects based on consideration of final report recommendations.

Integration of the Mississippi River Gulf Outlet Deep-Draft De-authorization Report

In the Emergency Supplemental Appropriations Act for Defense, the Global War on Terror, and Hurricane Recovery, 2006 (Public Law 109-234), the U.S. Congress directed the Secretary of the Army, acting through the Chief of Engineers, to develop a comprehensive plan for de-authorization of deep-draft navigation on the Mississippi River-Gulf Outlet (MRGO). The USACE published an Integrated Final Report to Congress and Legislative Environmental Impact Statement for the Mississippi River – Gulf Outlet Deep-Draft De-authorization Study in November 2007, which is available on the internet at *http://mrgo.usace.army.mil*. The report recommends decommissioning the navigation channel and installing a total closure structure across the channel near Hopedale, Louisiana. The recommendation is consistent with the State of Louisiana’s Master Plan for Coastal Protection and Restoration.

In addition, the Final Report to Congress for the MRGO Deep-Draft De-authorization Study addresses Section 7013(a)(3)(B) of Water Resources Development Act 2007. Current LACPR alternatives also address items contained in the Water Resources Development Act 2007. These alternatives include:

1. Physical modification of the MRGO channel and restoration of affected areas;
2. Restore of natural features of the ecosystem to reduce or prevent storm surge damage;
3. Prevention of saltwater intrusion into the waterway; and

4. Efforts to integrate the recommendations of the report with the program authorized under Section 7003 (LCA) and the analysis and design authorized by title I of the Energy and Water Development Appropriations Act, 2006 (119 Stat. 2247).

These plans will be further integrated and developed as part of LACPR and will be considered for authorization and implementation under LACPR or other authorities. Also, the Operation and Maintenance measures authorized in Public Law 109-234, will remain authorized and will be implemented conditioned on the non-Federal sponsor assuming responsibility for 100 percent of the expense of operation, maintenance, repair, rehabilitation, and replacement for any constructed measures. These measures were authorized for “the repair, construction or provision of measures or structures necessary to protect, restore or increase wetlands, to prevent saltwater intrusion or storm surge.”

Evaluation of Recommendations from the Dutch Perspective

Following Hurricane Katrina, the Dutch Rijkswaterstaat offered its engineering expertise in an effort to help solve the problems in coastal Louisiana. Although the challenges faced in the Netherlands are not identical to those faced in South Louisiana, their thousand years of experience in protecting their land from inundation can provide valuable lessons in planning and designing an improved hurricane risk reduction system for South Louisiana. Based on the Memorandum of Agreement between the Dutch Rijkswaterstaat and the USACE a number of workshops and reviews were organized.

As part of the LACPR effort, the Dutch Rijkswaterstaat and Netherlands Water Partnership, a Dutch consortium of government agencies, researchers, and consultants, produced a report titled *A Dutch Perspective on Coastal Louisiana: Flood Risk Reduction and Landscape Stabilization.* The purpose of the Dutch Perspective report was to obtain an independent view of protection and restoration issues for the Louisiana coastal area from the Dutch based on their experience in dealing with similar issues in The Netherlands. Their report was prepared in parallel with the technical report and was not intended to provide information directly into the technical analysis at this stage; however, after reviewing the Dutch report, the team has concluded that the alternatives and issues in the Dutch Perspective report are not that different than those in the LACPR Technical Report. This consistency provides assurance that LACPR is being formulated correctly.

The Dutch report only addresses Planning Units 1 and 2. In Planning Unit 1, the Dutch essentially looked at the same alternatives as LACPR, i.e. barrier-weir (closed coast) vs. high level (open coast). Because of the limitations of their hydraulic and benefits analysis, they did not come to a firm conclusion as to which would be recommended. Those two strategies will be presented to stakeholders through the MCDA process. In Planning Unit 2, the Dutch again looked at an open vs. closed coast which corresponds to the LACPR ridge vs. barrier-weir strategies. The Dutch recommended the open coast strategy which will be presented to stakeholders as the ridge plan. The Dutch report will be a continuing reference document as LACPR moves towards possible recommendations and future feasibility studies. The continuing cooperation and exchange with the Dutch is, and should continue to be, an integral part of the LACPR effort.

Section 10. Conclusion

In response to the destruction caused by the 2005 Hurricanes Katrina and Rita, both the Louisiana Legislature and the United States Congress provided legislative directives to their respective agencies to investigate and integrate hurricane risk reduction and coastal restoration for South Louisiana. Development of plans to meet these directives was undertaken as a joint effort of the Federal government and the State of Louisiana. Although the State and Federal legislative directives are not identical, they share the common fundamental objective of creating the first plan in Louisiana's history designed to fully integrate hurricane risk reduction for coastal communities and industries with the restoration of the State's rapidly deteriorating coastal wetlands. This conclusion summarizes work performed to date, findings to date, and challenges ahead for the LACPR effort.

Work Performed to Date

The work performed to date provides the technical foundation for assessing risks and producing risk reduction plans for South Louisiana. At this point, the team has completed work as follows:

- Published the Preliminary Technical Report in July 2006.
- Defined the range and magnitude of storm threats effecting the Louisiana coast through the development of new computer modeling applications;
- Created a geographic information system (GIS) to comprehensively inventory assets at risk in Coastal Louisiana.
- Developed a numerical model to evaluate the potential land building alternatives based on Mississippi River Diversions.
- Developed a range of potential future condition scenarios to test the performance of alternative plans;
- Formulated and screened individual measures and alternative plans including structural, nonstructural, and coastal restoration components;
- Published the LACPR Plan Formulation Atlas on April 16, 2007 to document hundreds of measures under consideration for reducing risk in coastal Louisiana.
- Established a range of metrics to measure alternative plan performance using multi-criteria decision analysis;
- Conducted technical evaluations of alternative plans to generate metric output values;
- Solicited stakeholder input to gauge the relative value of each performance metric through a multi-criteria decision analysis (MCDA);
- Performed initial tests on the influence of various weighted metric values on overall plan performance outputs;
- Established new computer program applications to manage and process data, support analyses, and produce plan performance data;

- Documented metric outputs for each alternative plan; and
- Engaged stakeholders and the general public in the LACPR planning process beginning in September 2006.

The work performed to date provides the information needed to engage stakeholders in the assembly of a comprehensive and implementable plan to reduce hurricane storm-surge flooding risk in South Louisiana.

Findings to Date

The team now has a better understanding of the risk associated with a large range of hurricanes that could strike the Louisiana coast. The team has developed a number of alternative plans that could address a range of potential storm risks. These alternative plans have been evaluated using a range of potential future scenario with varying relative sea level rise, subsidence rates, economic growth, and population trends. The performance of alternative plans under the range of future scenarios was evaluated to generate outputs for many metrics. Analysis of the technical information developed a number of preliminary conclusions. Significant findings include:

- **The size and magnitude of storm threat are generally greater in the area of the central Gulf Coast near the Mississippi River.** Statistical analysis of historic storm data indicates the potential for occurrence of larger more intense storms (Category 2 or greater) increases toward the center of the Gulf Coast near the Mississippi River. The area of the Gulf Coast from roughly Panama City, Florida to New Iberia, Louisiana is approximately 1.5 times more likely to experience a Category 2 or greater storm than the remainder of the Gulf Coast. The area from roughly Mobile, Alabama to Grand Isle, Louisiana is twice as likely to experience storms of that magnitude.
- **Population forecasts are linked to the projection of long-term employment opportunity.** Coastal Louisiana will continue to be a population and employment center because many industries are specifically linked to resources that are located in Coastal Louisiana. Examples include port facilities, oil and gas reserves, navigation fabrication facilities, and commercial fisheries that are directly linked to the Gulf of Mexico, the Mississippi River, and other geographic features of coastal Louisiana. Many employment opportunities will continue to exist in these and other economic sectors. These opportunities, the associated populations, and resulting public and private investments are unlikely to be relocated from coastal Louisiana.
- **Protecting and restoring coastal wetlands is a critical component of the long-term survival of communities in coastal Louisiana.** Continuing erosion of wetlands and barrier islands reduces the natural buffer separating communities from the Gulf of Mexico. As these buffers disappear, communities will face a choice of building higher and stronger structural defenses; relocating to areas with lower risks; or continuing to live in areas under ever-increasing risk. As a result, the inclusion of some coastal restoration components in every alternative plan is fundamental to successful long-term risk reduction.
- **Individual and community decisions will play a strong role in determining future risks to both life and property.** Individuals and communities must decide where and

how to rebuild recognizing hurricane threats and risks inherent to life in South Louisiana. They must decide whether or not to remain in known flood hazard areas. Local governments have a role in implementing certain nonstructural measures such as land use planning, zoning, and permitting, which can help guide individual decisions.

- **Structural measures are not always the best solution.** In densely populated areas like greater New Orleans, structural features, such as new levees and floodwalls, may be a needed component of an overall risk reduction strategy. However, such measures may not be the best overall choice for risk reduction in all areas of the coast. Structural features are expensive and consideration must be given to the location of these features considering environmental impacts, resource availability, and potential unintended consequences.

- **Nonstructural approaches provide the most definitive risk reduction.** The total relocation or removal of assets from a flood affected zone, or elevation of assets above the flood affected zone, can significantly and reliably reduce risks.

- **A multiple lines of defense strategy has advantages over single strategy approaches.** Evaluating implementation challenges provides insight into alternative plan effectiveness and can be used to help justify development of redundant, integrated plan components. Understanding the weaknesses of individual measures also allows planners to assemble complementary measures that reduce exposure to risk and serve to foster development of comprehensive problem-solving approaches. Single strategy approaches have limitations, which are described below:

    - **<u>Coastal restoration efforts.</u>** Depending solely on coastal restoration could protract additional risk over time due to the, increasing vulnerability of wetlands. A single major storm event can leave communities depending exclusively upon the protection of wetlands as a buffer more exposed to future risk. A number of elements threaten the health and continued vitality of coastal wetlands. The impacts of Hurricanes Katrina and Rita serve as an example of protracted risk. Those storms destroyed or severely damaged over 200 square miles of wetlands along the Louisiana coast. Those wetlands currently are unable to provide buffering protection. Conversely, communities that rely on a combination of protective strategies including wetlands, elevated homes, levees, floodwalls and floodgates are at much less risk over time.
    - **<u>Nonstructural measures.</u>** Properties raised above determined flood elevations are less prone to storm-related risk than those located in flood hazard areas. Consequently, a strategy for programmatic implementation of nonstructural measures is proposed for those properties at higher risk. However, implementation of a nonstructural strategy must account for other considerations such as historic preservation, public acceptance, and site-specific engineering feasibility. A voluntary nonstructural strategy may not achieve 100 percent participation without intense stakeholder involvement, leaving some locations vulnerable to storm-damage risk. Therefore, complete implementation of a nonstructural-only strategy is not likely without commitment from State and local leaders. Creation of a long-term risk reduction program through nonstructural measures would require collaboration between Federal, State and local agencies.

- **<u>Structural components</u>.** Following the 2005 storm season, the USACE placed high emphasis on evaluating the New Orleans area levees, including understanding the performance of the levees during hurricanes and identifying design and construction improvements to enhance system resiliency. A key lesson learned is that protecting urban areas through a single levee alignment places that community at extreme risk from a single levee failure. Incorporating redundancies and other components into a hurricane storm-surge risk reduction plan is a better systems approach. Structural measures may be the only effective or viable strategy to reduce damage to highly urbanized areas or to critical infrastructure; however, even greater effectiveness can be achieved through a strategy utilizing multiple lines of defense.

Challenges Ahead

Efforts to date do not point to a single effective risk reduction strategy. No single strategy for comprehensive hurricane damage risk reduction, other than entirely abandoning communities in South Louisiana, will guarantee safety for the population along the coast. However, the economic, ecological and cultural values produced in South Louisiana collectively justify continuing efforts to find implementable risk reduction strategies.

An integrated comprehensive system comprised of coastal restoration efforts, nonstructural measures, and structural components, is the most promising approach for reducing storm surge risk in South Louisiana. Many steps remain to effectively assemble plan features into one coastwide comprehensive plan utilizing a multiple lines of defense strategy.

Reducing storm-surge risks for communities in the complex geomorphologic setting of South Louisiana is a challenge, which often influences project costs. Traditional investment assessment of the costs of projects does not produce a positive return when applied across the coast. However, these assessments do not fully recognize the strategic, historic and ecological values of the area. Therefore, identification of a risk reduction plan must consider economic and other factors and weigh those against residual risks or against the abandonment of some communities or against the loss of coastal ecological productivity.

The technical results presented in this report are not conclusive findings, but rather, serve as a basis for the path ahead. Refinements to the technical evaluation must be completed in order to reliably rank and compare alternative plans. Stakeholder involvement will be critical to the next steps in this process. At stakeholder workshops, the LACPR team hopes to share meaningful information with stakeholders in order to gather input which will guide the ranking of alternative plans, and give stakeholders the opportunity to participate in the decision-making process. Ultimately, preferred plan selection is based on a group decision process from which no single best solution is likely to emerge, but through which multiple criteria and perspectives can be incorporated into the coastwide comprehensive plans for Louisiana.

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